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Interagency Rangeland Water Erosion Project Report and State Data Summaries

United States Department of Agriculture

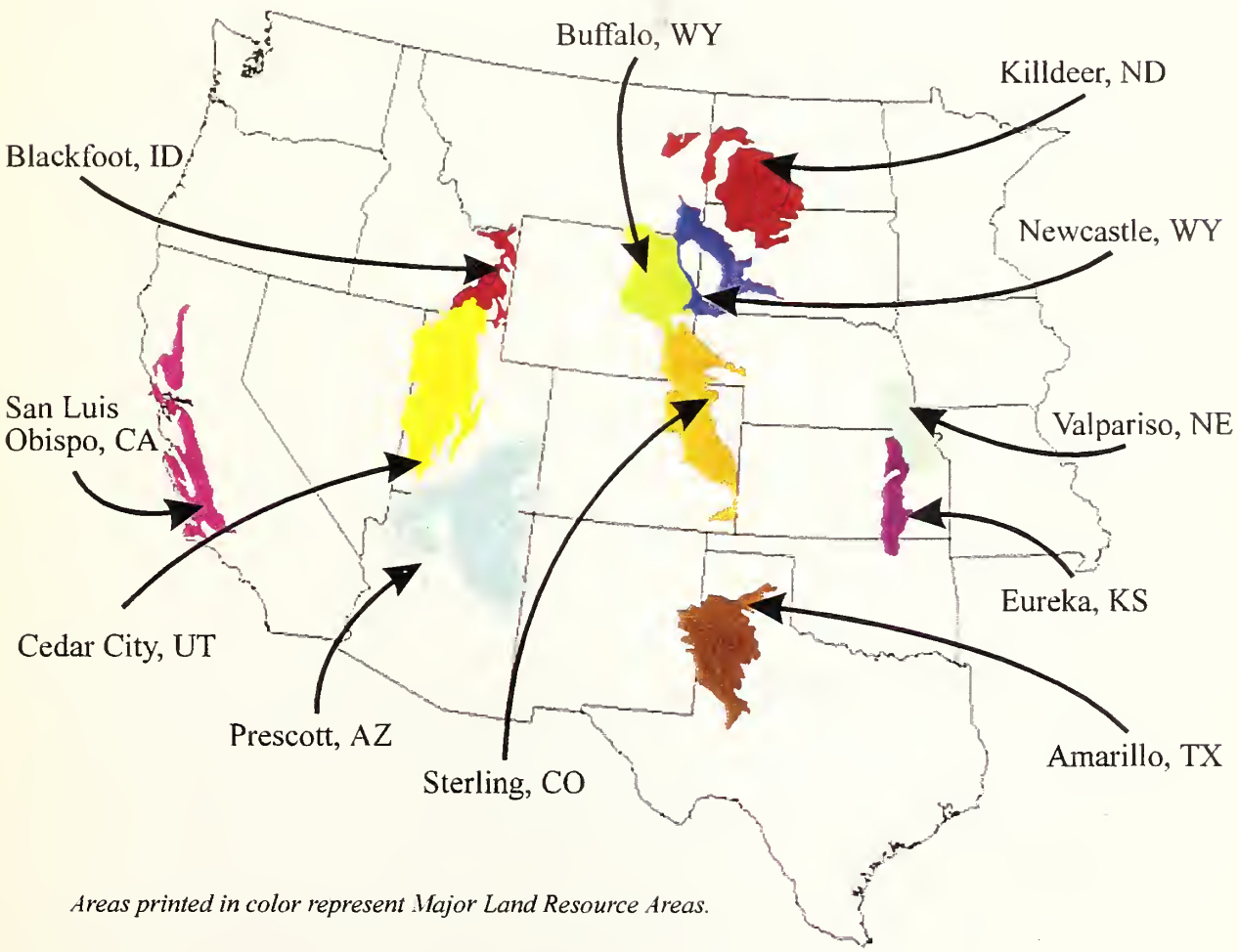
Agricultural Research Service

Natural Resources Conservation Service

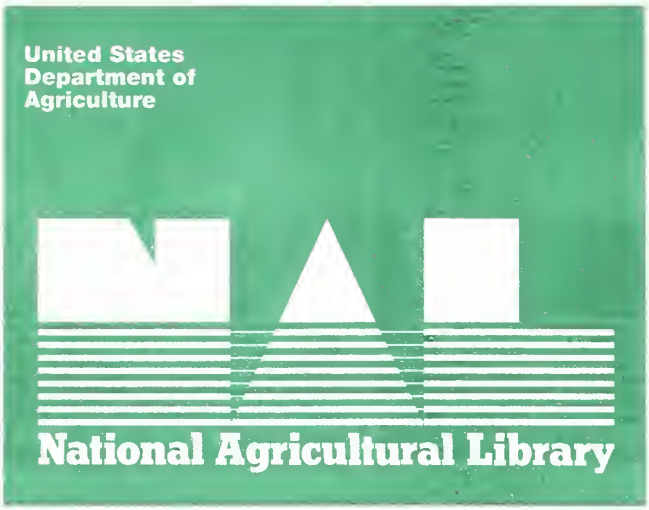
NWRC 98-1
August 1998

Interagency Rangeland Water Erosion Team (IRWET) and National Range Study Team (NRST)

NRST's Rainfall Simulation Sites



Areas printed in color represent Major Land Resource Areas.



The information in th rvice (NRCS) and the Agri er Erosion Project and includes i dy Team (NRST) Hydrology d tween NRCS and ARS to improve the understanding of the influence of vegetation on hydrologic characteristics over a wide spectrum of rangeland plant community types and to provide data to further the science and enhance rangeland hydrology models, namely the Water Erosion Prediction Project (WEPP).

From 1990-1993, the NRCS and ARS collaborated on a field study which involved conducting rainfall simulation studies in 10 states and at 26 sites (a total of 156 plots). The NRCS's National Range Study Team conducted the field effort. The basic objectives were to conduct the field rainfall simulation experiments with an emphasis on soil, plant, and hydrology for selected rangeland plant community types. An Interagency Water Erosion Team (IRWET) was also formed to work with the NRST and included NRCS and ARS personnel. The purpose of IRWET was to facilitate communication between NRCS and ARS, assist with the experimental design and field methodologies, reduce the data set and create a data base, interpret and analyze the data to enhance WEPP, and provide parameter data sets for the WEPP model.

This report includes basic summaries of the respective study locations, soils, plants, and hydrology data and an overview of how the data were used in support of the WEPP modeling effort. Analysis and interpretation of the NRST data set appears in published scientific journal papers (see final bibliography), symposia papers, and technical notes. Analysis and publication of studies using the NRST data will be forthcoming for years to come.

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Interagency Rangeland Water Erosion Project Report and State Data Summaries

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TABLE OF CONTENTS

I. ARS-NRCS Interagency Rangeland Water Erosion Project Summary 1

II. Using the Information Found in This Report 4

III. Extrapolation of Data
How to Use the NRST MLRA Map and Map of Additional MLRAs 5
How to Use the NRST Dataset 5
How to Use the Summary Tables 5

IV. Summary of NRST Data
Introduction 11
Land Use Features 11
Plant Community Features 13
Pertinent Soil Features 16

V. Site Selection and Study Design
Introduction 21
Site Selection 21
Basic Study Design 22
Site Level Soil Properties 22

VI. Data Collection and Measurement Methods
Plot Level Soil Properties 23
Plot Level Vegetation Properties 23
Rainfall Simulation 24

Individual State Data Summaries
Arizona 27
California 35
Colorado 41
Idaho 49
Kansas 57
Nebraska 67
North Dakota 75
Texas 85
Utah 93
Wyoming (Central Eastern) 101
Wyoming (Northeastern) 109

Bibliography 117

Tables and Figures

Figure 1 - NRST Major Land Resource Areas Map 6
Figure 2 - NRST Additional Major Land Resource Areas Map 7
Table A - NRST Site, Soils, and Plant Communities Summary Table 8
Table B - Classification of NRST Soils 10
Table C - Names of MLRA's 10
Table D - Land Use Features 12
Table E - Plant Community Features 14
Table F - Pertinent Soil Features 19

I. ARS/NRCS Interagency Rangeland Water Erosion Project Summary

Society continues to place great emphasis on water quantity and quality issues, adding new dimensions to the value of rangelands and reinforcing the concept of multiple use management. The Soil and Water Resources Conservation Act of 1977, the National Clean Water Act, and the 1985 Food Security Act identify erosion and improvement of water quality and quantity among our nation's highest resource priorities. Since rangelands comprise vast watershed areas in the United States, it is of prime importance for policies and activities to be formulated and implemented which address rangeland resource degradation.

The hydrologic response of any rangeland site results from the complex interactions of many soil and vegetation factors. Rangeland ecosystems are not homogeneous, even within seemingly continuous unbroken expanses of grass. In most rangeland plant communities, mosaic spatial patterns of different soils and vegetation prevail, which vary with season and management. Both the type and amount of vegetation significantly influence the spatial and temporal variability of hydrologic processes, including interception, infiltration, evaporation, transpiration, percolation, surface runoff, soil water storage, soil erosion, and deposition of sediment (Rauzi et al., 1968; Blackburn, 1975; Hanson et al., 1978; Blackburn, 1984; Gifford, 1984; Swanson and Buckhouse, 1984; Blackburn et al., 1986; Johnson and Gordon, 1988; Thurow et al., 1988; Wilcox and Wood, 1989; Spaeth, 1990; Blackburn et al., 1990; Blackburn et al., 1992). This has significant range management implications, in that vegetation characteristics can be used to manipulate and predict water quantity and quality from rangeland watersheds (Heede, 1979; Blackburn, 1983; Hibbert, 1983; Thurow et al., 1988; Griffin and McCarl, 1989).

Our understanding of vegetation and hydrology inter-relationships is far from complete. Better data bases and new quantitative methods are needed to further enhance our understanding of watershed processes and to develop better management tools. The United States Department of Agriculture, Natural Resource Conservation Service (USDA, NRCS) is mandated to support proper management of privately held rangelands. To remain technical credibility, the NRCS needs state of the art methods for predicting erosion and water yields from rangelands. Currently, the NRCS generally uses the Hydrologic Curve Number method (USDA, SCS, 1993) and the Universal Soil Loss Equation (USLE) (Wischmeirer and Smith, 1965, 1978) to predict runoff and erosion. The Hydrologic Curve Number came into use in the mid-1950s and the USLE was implemented in the mid-1960s. Both technologies have widely recognized limitations when applied to rangelands, pasture lands, and forest lands. The USLE is an empirical model developed from years of cropland data from the Central and Eastern United States. Most of the management methods and techniques addressed by the USLE model are not directly applicable to rangeland conditions. Enhanced hydrology and erosion prediction technology is needed to offer credence for projections associated with conservation planning, national inventories, and various program implementation guidelines.

In 1987, the USDA, Agricultural Research Service (ARS), the USDA, SCS, the USDA, Forest Service (FS), and the United States Department of Interior, Bureau of Land Management (USDI, BLM) developed technology called the Water Erosion Prediction Project (WEPP). From the onset, WEPP identified specific model components to address the unique and diverse aspects of rangelands. Limited field data on rangelands were collected during the summers of 1987 and 1988 and used to begin developing rangeland model components. However, it soon became apparent that additional data were needed for model enhancement, validation, and parameterization, if the WEPP model was to be applied over a wide spectrum of rangeland sites and conditions. An ARS/NRCS interagency cooperative effort was then initiated to improve our scientific understanding of the influence of rangeland vegetation on hydrologic response from a wide range of soils and climatic conditions and to improve our predictive capabilities for simulating such interactions by improving, validating and adding parameters to the WEPP model for use on rangelands.

Project Objectives:

The project consisted of a two team effort consisting of the NRCS National Range Study Team (NRST) and the ARS/NRCS Interagency Rangeland Water Erosion Team (IRWET).

The charge for the NRST was to collect scientifically creditable vegetation, soil, and hydrology information from a wide variety of rangeland sites and transfer that data to IRWET for analysis and interpretation. The NRST effort was very successful in collecting quality data from 26 sites in 10 western states and successfully transferring the data to IRWET. Much of the remainder of this reports summarizes the NRST data, including suggestions on how NRCS personnel and other users can use the data at the field level.

IRWET was charged with using the NRST and other experimental data sets to improve the plant/soil relationships within the WEPP model to better address the influence of vegetation induced spatial variability on the hydrology and erosion responses from rangelands. Efforts were coordinated closely with the WEPP model development at the ARS, National Soil Erosion Laboratory to insure that the IRWET objectives and activities were compatible with the overall WEPP effort. NRST data were used to improve parameter estimation procedures for the rangeland infiltration and erosion components of the WEPP model. The data were also used to validate components of the WEPP model and target components for future enhancement. IRWET also supported technology transfer efforts between NRCS and ARS by analyzing and interpreting collected data and published the results in appropriate scientific journals and technical materials for NRCS. Parameter data sets for running the WEPP model for all sampled rangeland sites were also developed and transferred to appropriate ARS and NRCS personnel. The IRWET effort also included many university scientists, as well, through cooperative projects aimed at improving and validating the rangeland components of the WEPP model.

IRWET Products:

1. A complete data set on plant communities, soils, runoff, and erosion for use in developing hydrologic relationships for varying rangeland plant communities and soils types.

2. A national data set on rangeland erosion, hydrology, soils, and vegetation for validation and enhancement of the rangeland components of hydrologic models such as WEPP and SPUR.

3. Data for inclusion into NRCS national range and soil databases.

4. Enhanced hydrology, erosion, and vegetation components of the WEPP model that have been validated for selected rangeland sites.

5. Enhanced procedures for establishing parameters for rangeland components of the WEPP model documented in the 1995 version of the model, Model User Guide and Model Documentation (USDA-ARS 1995).

6. Rangeland parameter data sets for both the single event and continuous versions of the WEPP model on all NRST sites to aid NRCS state, area, and field office personnel.

7. Two symposiums at the Society for Range Management and Soil Science Society of America National Meetings.

8. Over 75 refereed journal articles, workshops and symposium proceedings, technical notes, bulletins, and presentations.

9. Oral and written reports for NRCS and ARS Administration.

10. Highly trained NRCS personnel for implementing the rangeland version of WEPP within the NRCS.

II. Using The Information Found In This Report

Benchmark Sites - A New Concept
This dataset was developed using the Benchmark Site concept (Franks et al., 1993) for site selection. This project serves as a case study for use of this new site selection method. Benchmark sites represent an integrated approach which encompasses these three criteria for a selected site:

1. Benchmark Plant Community
2. Representative or Benchmark Soil
3. Known Management History

How Benchmark Sites Were Selected
This site selection method was developed to target soils and plant communities representative of large geographic areas. One of the most important factors considered in site selection was the potential use of this data to develop interpretations that apply to more than just the 11 site locations (26 total sites) actually studied. Through Benchmark Site Selection, we were able to take advantage of the existing concept of benchmark or representative soils, expand upon it, add additional criteria, develop the concept of benchmark range sites, and add the component of management history. This greatly increases the utility of the data.

Each site was selected on a representative soil within a Major Land Resource Area (MLRA) (Figure 1). MLRA's are delineated on a small scale because they contain within their boundaries similar soils, climate, and land uses (USDA, SCS, 1981). The information from the individual sites does not represent all soils or range sites within a MLRA. However, each study site is representative of the selected soil/site. Each study site has applicability to that soil and range site, and similar soils with similar plant communities within the specified MLRA.

The NRCS soil survey database (which contains information on the location, acreage, and other attributes of the soil) was used to build a map of additional MLRAs where the selected representative soils occur (Figure 2). The data from the NRST sites can be applied to some other areas within these MLRAs as well, based on plant communities and associated soil types. The sites in the study do not represent all of the soils and conditions within these additional MLRAs, but do have applicability to similar soils and plant communities within these additional MLRAs.

Benchmark Sites help answer the question of how far the data can be extrapolated, with any confidence, based on soil attributes already recorded in the NRCS Soil Survey Database. However, since any study of this nature is complex, the information generated must be used appropriately. All of the information presented here has been screened and validated to be as accurate as possible but this does not guarantee that it will be appropriate for any specific analysis. The validity of the information for an intended purpose and the decision to include or exclude specific plots must be made after careful review of the study design and the methods used to collect and process the information.

III. Extrapolation of Data

How to Use the NRST Major Land Resource Areas Map
The MLRA in which a particular Benchmark Site occurs is displayed on the NRST Major Land Resource Areas Map (Figure 1). Table A presents a list of the MLRAs where individual sites occur. The maps and table A are intended to help users decide if information from a particular site may be useful to them. Users who do not work at or near a particular site, but within the designated MLRA, may be able to use that site information, as well.

How to Use the Map of Additional Major Land Resource Areas Map
All of the Major Land Resource Areas (MLRA) where the soil series found on a particular NRST site also occur are displayed on the NRST Additional Major Land Resource Areas Map (Figure 2). Table B provides a list of all of the MLRAs where the soil series occur. This map and table B are intended to help users to decide if information from a particular site may be of some use to them even if their area falls outside a particular site's own MLRA. Users who do not work at or near a site's designated MLRA may be able to use that site information as well on similar soils with similar plant communities if their area occurs within the shaded area of other MLRAs.

How to Use the NRST Dataset
Information found within each state summary includes soil series, map unit, range site name, range cover type, and information about the plant community for each vegetation state found on the sites. Additional information about range sites can be found in the NRCS National Range and Pasture Handbook, and each state maintains complete range site descriptions for their state. Soil survey information can be obtained from the local field office, state office, or Major Land Resource Area (MO) office.

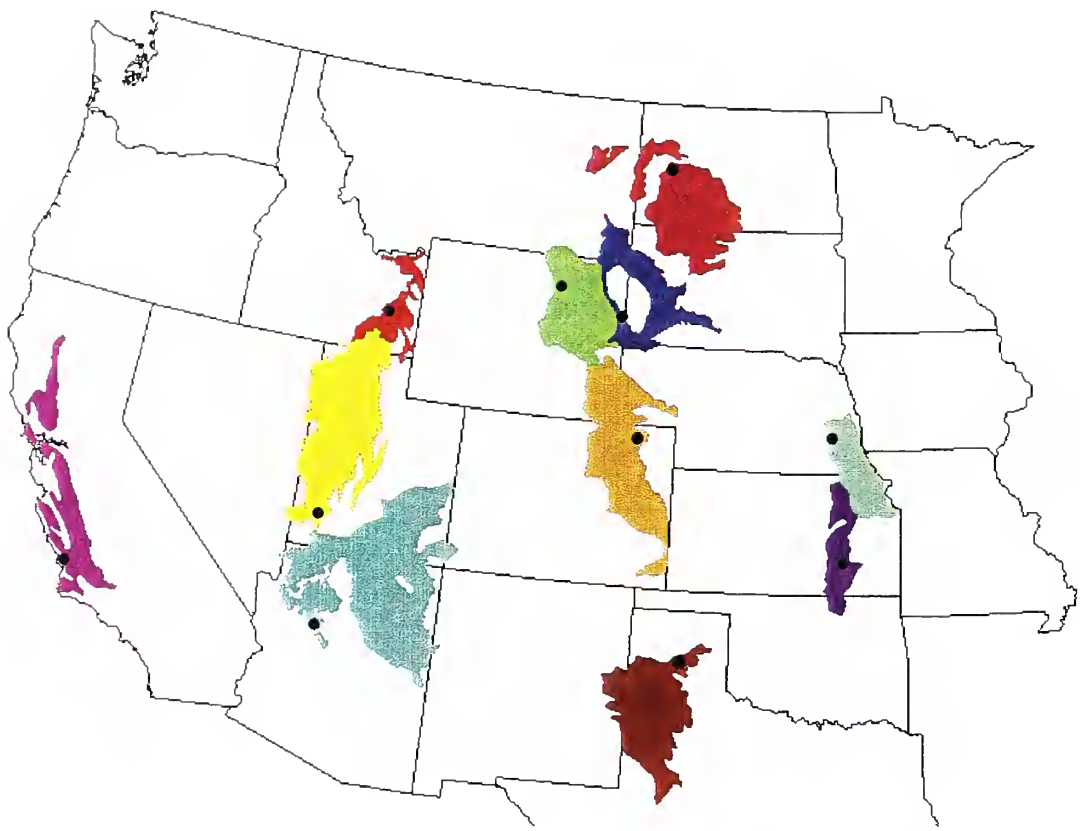
This data was used in the development of the Rangeland Component of WEPP. WEPP is among the new generation of models with parameters under development for erosion prediction. The data provided can be used to run the single event WEPP model for predictive purposes. This can also be used for a variety of other purposes, such as gradient analysis of plant community characteristics (Spaeth et al., 1996), hydrologic assessments (Blackburn and Pierson, 1994), impacts of past management on plant communities and soils, various resource assessments such as rangeland health and soil quality, etc. This data is field measured and does not represent an estimate.

How to Use the Summary Tables A, B and C at the end of this section
Table A is arranged by site designation and state. It contains the soil series name, MLRA, Land Resource Region (LRR), Range Site name and number, Range Cover Region and Range Cover Type. Table B is arranged alphabetically by soil series name and contains the taxonomic classification of each soil series and the MLRAs where these soil series occur. Table C is arranged by MLRA and contains the descriptive names of all of the other MLRA's where the soil series studied also occur.

For example, two sites on the Taylors Flat soil were studied near Cedar City, Utah. In addition to MLRA D28a where the two Taylors Flat sites occur, the Taylors Flat soil occurs in MLRA 28b, as well. Soils similar to Taylors Flat occur in MLRA 28b, as do plant communities similar to the Semidesert Loam range site. Therefore, the results of this information should be of use in those similar soils and plant communities in MLRA D28b.

National Range Study Team (NRST)

Major Land Resource Areas where NRST sites occur

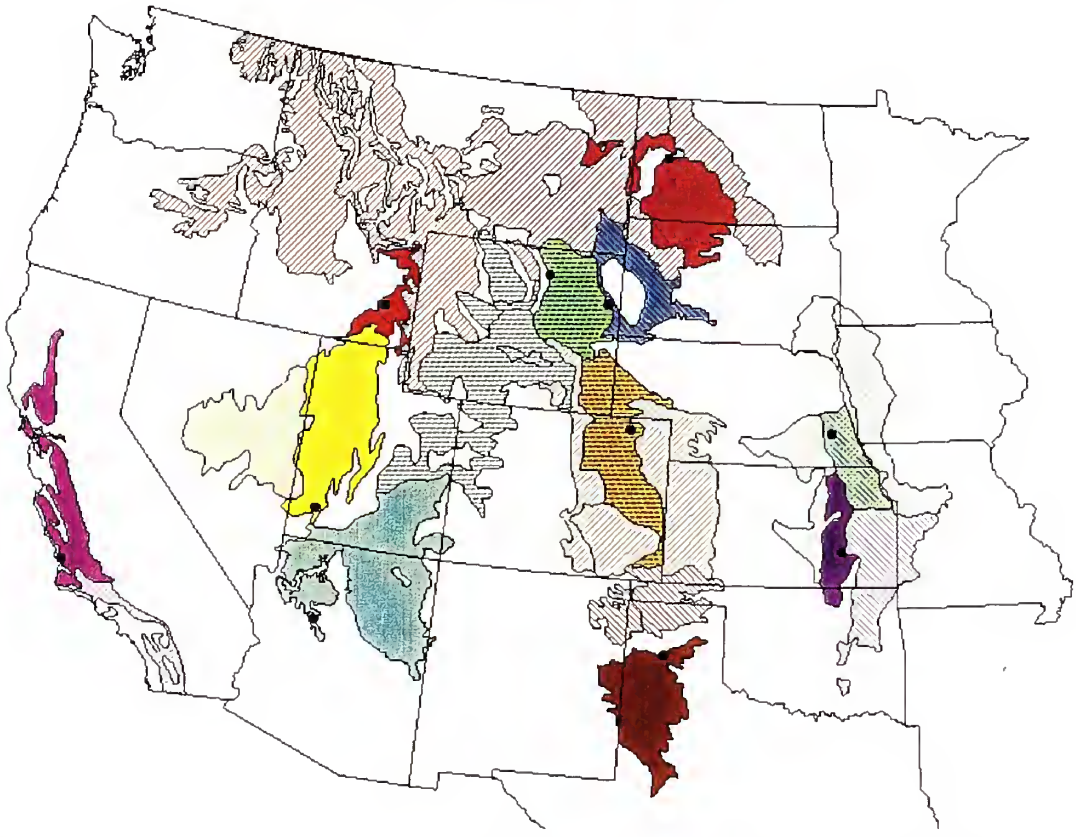


Color	Site Designation	State	MLRA
	B	Nebraska	M106
	C	Texas	H77
	E	Kansas	H76
	F	Colorado	G67
	G	Wyoming	G60A
	H	North Dakota	F54
	I	Wyoming	G58B
	J	Idaho	A13
	K	Arizona	D35
	L	California	C15
	M	Utah	D28A

FIGURE 1 - NRST MAJOR LAND RESOURCE AREAS MAP

This map shows the geographic distribution of the Major Land Resource Areas (MLRAs) where NRST sites are found. NRST data can be extrapolated to apply to similar soils and plant communities within the designated MLRA. Map source is Major Land Resource Areas of the United States, NRCS, National Soil Survey Center, 1997. Table A defines the respective MLRA for each state.

Additional Major Land Resource Areas where the soil series found at an NRST site also occurs



Color	Site Designation	State	MLRA	Additional MLRAs
	B	Nebraska	M106	107, 75, 102B
	C	Texas	H77	78, 78A
	E	Kansas	H76	76, 106, 112
	F	Colorado	G67	69, 72, 49
	G	Wyoming	G60A	32, 33, 58B, 34, 67
	H	North Dakota	F54	53A, 53B, 58B, 58A
	I	Wyoming	G58B	32, 33, 34, 60A, 67
	J	Idaho	A13	43
	K	Arizona	D35	39, 36
	L	California	C15	20
	M	Utah	D28A	28B

FIGURE 2 - NRST ADDITIONAL MAJOR LAND RESOURCE AREAS MAP

This map shows the geographic distribution of additional MLRAs where the NRST data may be extrapolated to similar soils and similar regions within these MLRAs. These additional MLRAs were selected because the Soil Interpretation Records (NRCS, National Soils Information System (NASIS), 1997) for the Soil Series found on the NRST sites indicate that these Soil Series also occur within these additional MLRAs. Some MLRAs found on the Soil Interpretation Records were excluded because of poor fit with the plant communities, range cover regions, and range cover types (Shiflet, 1994). Map source is Major Land Resource Areas of the United States, NRCS, National Soil Survey Center, 1997. Table C provides the descriptive names of the additional MLRAs.

TABLE A. NRST Sites, Soils, and Plant Communities Summary Table

Lists Soil Series name, Major Land Resource Area (MLRA) #'s, MLRA names, Land Resource Regions (LRR), NRCS Range Site Name and #'s, Range Cover Regions and Range Cover Types in alphabetical order by NRST Site designation and State. Soil Series names are from NRCS National Soil Information System (NASIS, 1997). MLRA, LRR (USDA Soil Conservation Service, 1981), and Range Site data source is NRCS Field Office Technical Guides, 1997. Range Cover Regions and Range Cover Types (Shiflet, 1994) information was matched with NRST data.

Site	State	Soil Series	MLRA#	MLRA Name	Land Resource Region	Range Site Name	Range Site#	Range Cover Region	Range Cover Type
B1	NE	Burchard	106	Nebraska and	M - Central Feed	Silty	106xy075NE	Northern	Bluestem Prairie
B2	NE	Burchard	106	and Kansas	Grains and	Silty	106xy075NE	Great Plains	Bluestem Prairie
				Loess - Drift Hills	Livestock Region				
C1	TX	Olton	77	Southern	H - Central Great	Deep Hardland	077cy022TX	Southern	Grama-Buffalograss
C2	TX	Olton	77	High Plains	Plains Winter Wheat	(PZ 25-34)	077cy022TX	Great Plains	Grama-Buffalograss
					and Range Region				
E1	KS	Martin	76	Bluestem	H - Central Great	Loamy Upland	076xy015KS	Northern	Bluestem Prairie
E2	KS	Martin	76	Hills	Plains Winter Wheat	Loamy Upland	076xy015KS	Great Plains	Bluestem Prairie
E3	KS	Martin	76		and Range Region	Loamy Upland	076xy015KS		Bluestem Prairie
F1	CO	Stoneham	67	Central	G - Western Great	Loamy Plains	067xy002CO	Northern	Grama-Buffalograss
F2	CO	Stoneham	67	High Plains	Plains Range and	Loamy Plains	067xy002CO	Great Plains	Grama-Buffalograss
F3	CO	Stoneham	67		Irrigated Region	Loamy Plains	067xy002CO		Grama-Buffalograss
G1	WY	Kishona	60A	Pierre Shale	G - Western Great	Loamy	058by122WY	Northern	Wheatgrass-
G2	WY	Kishona	60A	Plains and	Plains Range and	Loamy	058by122WY	Great Plains	Grama-
G3	WY	Kishona	60A	Badlands	Irrigated Region	Loamy	058by122WY		Needlegrass
H1	ND	Parshall	54	Rolling Soft	F - Northern Great	Sandy	054xy026ND	Northern	Praire Sandreed-
H2	ND	Parshall	54	Shale Plain	Plains Spring	Sandy	054xy026ND	Great Plains	Needlegrass
H3	ND	Parshall	54		Wheat Region	Sandy	054xy026ND		

Table A. (continued)

List of the Soil Series name, Major Land Resource Area (MLRA) #'s, MLRA names, Land Resource Regions (LRR), NRCS Range Site #'s, Range Cover Regions and Range Cover Types in alphabetical order by NRST Site designation and State. Soil Series names are from NRCS National Soil Information System (NASIS, 1997). MLRA, LRR (USDA Soil Conservation Service, 1981), and Range Site data source is NRCS Field Office Technical Guides, 1997. Range Cover Regions and Range Cover Types (Shiflet, 1994) information was matched with NRST data.

Site	State	Soil Series	MLRA#	MLRA Name	Land Resource Region	Range Site Name	Range Site#	Range Cover Region	Range Cover Type
I1 I2	WY WY	Forkwood Forkwood	58B 58B	Northern Rolling High Plains, Southern Part	G - Western Great Plains Range and Irrigated Region	Loamy Loamy	058by122WY 058by122WY	Northern Great Plains	Sagebrush-Grass in Wheatgrass-Grama-Needlegrass
J1 J2	ID ID	Robin Robin	13 13	Eastern Idaho Plateaus	B - Northwestern Winter Wheat and Range Region	Loamy(16-22) Loamy(16-22)	013xy023ID 013xy023ID	Great Basin Great Basin	Mountain Big Sagebrush
K1 K2	AZ AZ	Lonti Lonti	35 35	Colorado and Green River Plateaus	D - Western Range and Irrigated Region	Loamy Upland Loamy Upland	035xa113AZ 035xa113AZ	Southwestern Southwestern	Grama-Galleta Grama-Galleta
L1 L2	CA CA	Diablo Diablo	15 15	Central California Coast Range	C - California Subtropical Region	Clayey Clayey	None None	Pacific Southwest	Valley Grassland Valley Grassland
M1 M2	UT UT	Taylors Flat Taylors Flat	28A 28A	Great Salt Lake Area	D - Western Range and Irrigated Region	Semidesert Loam	028ay220UT 028ay220UT	Great Basin Great Basin	Wyoming Big Sagebrush

TABLE B. Classification of NRST Soils. List of the classification of all Soil Series found on the NRST sites. Source for Soil Series classification is NRCS National Soil Information System (NASIS), 1997 and Keys to Soil Taxonomy, Soil Survey Staff, 1996. Major Land Resource Areas (MLRA) source is Soil Interpretation Records (SIR's) for the Soil Series, NASIS, 1997.

Taxonomic Classification of NRST Soil Series and the MLRA's		
Soil Series	Classification	MLRA's *
Burchard	fine-loamy, mixed, mesic Typic Argiudolls	107,75,102b,106
Diablo	fine, smectitic, thermic Typic Haploxererts	15,20
Forkwood	fine-loamy, mixed mesic Ustic Haplargids	32,33,34,58b,60a,67
Kishona	fine-loamy, mixed (calcareous), mesic Ustic Torriorthents	32,33,58b,34,67,60a
Lonti	fine, mixed, mesic Ustic Haplargids	39,36
Martin(1)	fine, smectitic, mesic, Typic Hapluderts	76,106,112
Olton	fine, mixed, thermic, Aridic Paleustolls	77,78,78a
Parshall	coarse-loamy, mixed, Pachic Haploborolls	53a,53b,54,58b,58a
Robin	fine-silty, mixed, Cryic Pachic Paleborolls	13,43
Stoneham	fine-loamy, mixed, mesic, Aridic Haplustalfs	69,67,72,49
Taylorsflat	fine-loamy, mixed, mesic Xeric Haplocalcids	28a,28b
	(1) Taxadjunct to the Martin Series	

* Some MLRA's were omitted from this list due to poor fit with Range Cover Regions and Types (Shiflet,1994).

TABLE C. Names of MLRA's. List of the MLRA's and the descriptive name of each MLRA found in Figure 2 that do not appear in Table A. USDA, Ag Handbook 296 (USDA, 1981)

MLRA	NAME
20	Southern California Mountains
28B	Central Nevada Basin and Range
32	Northern Intermountain Desertic Basins
33	Semiarid Rocky Mountains
34	Central Desertic Basins, Mountains, and Plateaus
36	New Mexico and Arizona Plateaus and Mesas
39	Arizona and New Mexico Mountains
43	Northern Rocky Mountains
49	Southern Rocky Mountain Foothills
53A	Northern Dark Brown Glaciated Plains
53B	Central Dark Brown Glaciated Plains
58A	Northern Rolling High Plains, Northern Part
58B	Northern Rolling High Plains, Southern Part
60A	Pierre Shale Plains and Badlands
67	Central High Plains
69	Upper Arkansas Valley Rolling Plains
72	Central High Tableland
75	Central Loess Plains
76	Bluestem Hills
78	Central Rolling Red Plains
78A	Central Rolling Red Plains, Northern Part
102B	Loess Uplands and Till Plains
106	Nebraska and Kansas Loess-Drift Hills
107	Iowa and Missouri Deep Loess Hills
112	Cherokee Prairies

IV. Summary of NRST Data

Introduction

This section of the report is a general summary of the NRST data. The individual state data summaries are more detailed and are found in later sections. This section has three subsections, 1 Land Use Features, 2 Plant Community Features, and 3 Pertinent Soil Features. Within each subsection, the NRST state data is divided into useful groups that are valuable for resource managers, researchers, land owners, and other users to make interpretations or inferences from the data.

1. Land Use Features

This subsection includes land use features and groups the 11 site locations (26 individual sites) by Land Resource Region as found in Ag Handbook 296 (USDA, SCS, 1981).

The Land Use Features table is based on the Land Resource Regions and Major Land Resource Areas found in Ag Handbook 296 (USDA, SCS, 1981). Grouping at the Land Resource Region (LRR) level is the most general. There are 20 LRRs in the United States. Each LRR has a letter designation from A to U. Each LRR also has a descriptive name, such as D - Western Range and Irrigated. LRR-D encompasses about 1/4 of the western US. G - Western Range, and Irrigated covers about 1/8 of the western US. Within each LRR, several Major Land Resource Areas (MLRAs) occur. This grouping is still general in nature but is more detailed than for a Land Resource Region. MLRAs have geographic distribution and number designations such as 13 or 58. MLRA 58 has a descriptive title, as well, Northern Rolling High Plains, and occurs within LRR - G. MLRA 13 - Eastern Idaho Plateaus occurs within LRR - A. There are more than 150 MLRAs in the US. MLRAs are designed for data interpretation at the state level.

Major Land Resource Areas (MLRAs) delineate the geographic extent of similar areas with a particular pattern of soils, climate, water resources and land uses. MLRAs are designed to help land use planners and other users with statewide agricultural planning as well as the coordination of interstate, regional, and national planning. They provide information about land use, elevation and topography, climate, water, soils, and historic plant communities useful for farming, ranching, forestry, engineering, recreation, and other uses. More detailed information about MLRAs is available from the document cited above. Table D summarizes some of the information in this section and is organized in the following hierarchical manner.

Land Resource Regions (USDA, SCS, 1981)
  Major Land Resource Area (USDA, SCS, 1981)
    Soil Series and Range Site (USDA, NRCS, 1997)

Two sites (M and K) occur within LRR-D Western Range and Irrigated. Three sites (F, G and I) occur within LRR-G Western Great Plains Range and Irrigated. Two sites (C and E) occur within LRR-H Central Great Plains Winter Wheat and Range. These sites would be representative of the rangeland in these LRR's. The other four sites occur singly in LRR's A, C, F, and M.

TABLE D. Land Use Features. This table groups NRST sites by Land Resource Region.

	Land Resource Region	Major Land Resource Area	Soil Series	Range Site	Location	Sites
A	North Western Wheat and Range	13 Eastern Idaho Plateaus	Robin	Loamy (16-22)	Blackfoot, ID	J1, J2
C	California Subtropical Fruit, Truck, and Specialty Crop	15 Central California Coast Range	Diablo	Clayey	San Luis Obispo, CA	L1, L2
D	Western Range and Irrigated	28a Great Salt Lake Area 35 Colorado and Green River Plateau	Taylors Flat Lonti	Semidesert Loam Loamy Upland	Cedar City, UT Prescott, AZ	M1, M2 K1, K2
F	Northern Great Plains Spring Wheat	54 Rolling Soft Shale Plain	Parshall	Sandy	Killdeer, ND	H1, H2, H3
G	Western Great Plains Range and Irrigated	67 Central High Plains 60a Pierre Shale Plains and Badlands 58b Northern Rolling Plains, Southern Part	Stoneham Kishona Forkwood	Loamy Plains Loamy Loamy	Sterling, Co Newcastle, WY Buffalo, WY	F1, F2, F3 G1, G2, G3 I1, I2
H	Central Great Plains Winter Wheat and Range	77 Southern High Plains 76 Bluestem Hills	Olton Martin	Deep Hardland Loamy Upland	Amarillo, TX Eureka, KS	C1, C2 E1, E2, E3
M	Central Feed Grains and Livestock	106 Nebraska and Kansas Loess, Drift Hills	Burchard	Silty	Valparaiso, NE	B1, B2

2. Plant Community Features

This subsection groups NRST sites by Range Cover Regions and Range Cover Types (Shiflet, 1994). It also includes information about the range sites and soil series and well as a list of the three dominant plant species found at each site.

Range Cover Regions are the most general, and there are 10 of these regions in the US. Range Cover Regions are designed to group similar areas within the US and describe and catalog existing rangeland vegetation in a manner similar to that used for Forest Cover. Each region has a name and designates states where the region occurs. For example, Northern Great Plains - Plains areas of Montana, Wyoming, Colorado; the states of North Dakota, South Dakota, Nebraska, Kansas; and the prairie portion of Minnesota.

Range Cover Types are more detailed, and several may occur within a Range Cover Region. For example, Bluestem Prairie (601) occurs within the Northern Great Plains Cover Type. Table E also includes a brief list of plants commonly found within each Range Cover Type. More detailed information is available from the document cited above.

The Plant Communities Features Table E also identifies which NRCS Range Site occurs at the site location (11 total) and lists the dominant plant species found on each of the 26 individual sites. Range Cover Types and Range Sites do not have delineated geographic distribution but all fall within the areas delineated on the MLRA maps (figures 1 and 2). Table A summarizes some of the information in this section.

NRST sites occur in five of the ten Range Cover Regions. Six of the sites (B, E, G, H, I and F) occur within the Northern Great Plains cover region. Two of these sites (B and E) represent the Bluestem Prairie cover type. Two sites (G and H) represent the Wheatgrass-Grama-Needlegrass cover type. One site (I) represents the Sagebrush-Grass cover type. One site (F) represents the Blue Grama-Buffalo Grass cover type. Two of the sites (J and M) occur within the Great Basin (Sagebrush Types) cover region. Site J represents the Mountain Big Sagebrush cover type. Site M represents the Wyoming Big Sagebrush cover type. Site C represents the Grama-Buffalo Grass cover type within the Southern Great Plains cover region. Site K represents the Grama Galleta cover type within the Southwestern cover region. Site L represents the Valley Grassland cover type within the Pacific Southwest cover region.

TABLE E. Plant Community Features. This table groups NRST sites by Range Cover Regions and Range Cover Types. Plant Communities in Table E, are based on the SRM - Rangeland Cover Types of the United States (Shiflet, 1994). It groups the 26 sites (11 site locations) by Range Cover Regions and Range Cover Types.

Range Cover Regions	Range Cover Types	Typical Plant Species	NRST Site and State	Soil Series	Range Site	Dominant Plant Species On Site, in Descending Order (by weight)
Northern Great Plains	Bluestem Prairie (SRM 601)	big bluestem, switchgrass, Indiangrass, little bluestem	B1 - NE	Burchard	Silty	Kentucky bluegrass (*Poa pratensis*) Dandelion (*Taraxacum officinale*) Alsike clover (*Trifolium hybridum*)
			B2 - NE	Burchard	Silty	Primrose (*Primula* sp.) Porcupinegrass (*Hesperostipa spartea*) Big bluestem (*Andropogon gerardii*)
			E1 - KS	Martin	Loamy Upland	Annual broomweed (*Amphiachyris dracunculoides*) Missouri goldenrod (*Solidago missouriensis*) Tall dropseed (*Sporobolus compositus*)
			E2 - KS	Martin	Loamy Upland	Little bluestem (*Schizachyrium scoparium*) Big bluestem, Indiangrass (*Sorghastrum nutans*)
			E3 - KS	Martin	Loamy Upland	Buffalograss (*Buchloe dactyloides*) Sideoats grama (*Buteloua curtipendula*) Little bluestem
	Wheatgrass-Grama-Needlegrass (SRM 608)	wheatgrasses, needlegrasses, Junegrass, blue grama	G1 - WY	Kishona	Loamy	Prickly pear cactus (*Opuntia polyacantha*) Needleandthread (*Hesperostipa comata*) Threadleaf sedge (*Carex filifolia*)
			G2 - WY	Kishona	Loamy	Cheatgrass (*Bromus tectorum*) Needleandthread Blue grama (*Bouteloua gracilis*)
			G3 - WY	Kishona	Loamy	Needleandthread Threadleaf sedge Blue grama
			H1 - ND	Parshall	Sandy	Needleandthread Prairie sandreed (*Calamovilfa longifolia*) Sedges (*Carex* sp.)
			H2 - ND	Parshall	Sandy	Clubmoss (*Lycopodium dendroideum*) Sedges Crocus (*Anemone patens*)
			H3 -ND	Parshall	Sandy	Sedges Blue grama Clubmoss
	Sagebrush - Grass (SRM 612) (Occurs as small areas within Wheatgrass-Grama-Needlegrass and Wheatgrass-Needlegrass Range Cover Types	big sagebrush, dwarf sagebrush, bluebunch wheatgrass	I1 - WY	Forkwood	Loamy	Wyoming big sagebrush (*Artemisia tridentata* ssp. Wyomingensis) Prairie Junegrass (*Koeleria macrantha*) Western wheatgrass (*Pascopyrum smithii*)
			I2 - WY	Forkwood	Loamy	Western wheatgrass Bluebunch wheatgrass (*Pseudoroegenria spicata*) Prairie Junegrass

Table E continued

Northern Great Plains	Blue Grama - Buffalo Grass (SRM 611)	blue grama, buffalograss, hairy grama, western wheatgrass, sideoats grama, prickly pear ctus	F1 - CO	Stoneham	Loamy Plains	Blue grama Western wheatgrass Buffalograss
			F2 - CO	Stoneham	Loamy Plains	Blue grama Sun sedge (*Carex inops* ssp. *heliophila*) Bottlebrush squirreltail (*Elymus elymoides*)
			F3 - CO	Stoneham	Loamy Plains	Buffalograss Blue grama Prickly pear cactus
Southern Great Plains	Grama - Buffalo Grass (SRM 715)	blue grama, buffalograss	C1 - TX	Olton	Deep Hardland	Blue grama Buffalograss Prickly pear cactus
			C2 - TX	Olton	Deep Hardland	Buffalograss Blue grama Prickly pear cactus
Great Basin (Sagebrush Types)	Mountain Big Sagebrush (SRM 402)	mountain big sagebrush, Idaho fescue, bluebunch wheatgrass	J1 - ID	Robin	Loamy	Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) Letterman needlegrass (*Achnatherum lettermanii*) Sandberg bluegrass (*Poa secunda*)
			J2 - ID	Robin	Loamy	Letterman needlegrass Sandberg bluegrass Prairie Junegrass
	Wyoming Big Sagebrush (SRM 403	Wyoming big sagebrush, bluebunch wheatgrass, Sandberg's bluegrass	M1 - UT	Taylors Flat	Semidesert Loam	Wyoming big sagebrush Bottlebrush squirreltail Galleta (*Hilaria jamesii*)
			M2 - UT	Taylors Flat	Semidesert Loam	Galleta Purple threeawn (*Aristida purpurea*) Bottlebrush squirreltail
Southwestern	Grama Galleta (SRM 502)	blue grama, galleta	K1 - AZ	Lonti	Loamy Upland	Blue grama Goldenweed (*Haploppaus* sp.) Ring muhly (*Muhlenbergia torreyi*)
			K2 - AZ	Lonti	Loamy Upland	Blue grama Rubber rabbitbrush (*Chrysothamnus nauseosus* ssp. *nauseosus*) Threeawn (*Aristida* ssp.)
Pacific Southwest	Valley Grassland (SRM 215)	herbaceous annual plants *(Avena, Bromus, Festuca, Hordeum, Erodium, Trifolium, Madia, etc.*	L1 - CA	Diablo	Clayey	Cretanweed (*Hedypnois cretica*) Ryegrass (*Lolium* sp.) Burclover (*Medicago polymorpha)*
			L2 - CA	Diablo	Clayey	Ryegrass Purple falsebrome (*Brachypodium distachyon*) Slender oat (*Avena barbata*)

3. Pertinent Soil Features

This subsection groups site locations by significant soil features that affect use and management. It also groups site locations rather than individual sites, because 2 or 3 individual sites occur within one site location and they all have the same soil (11 total, in 10 states, rather than 26 individual sites).

The features selected for this grouping are some of those that have the greatest influence on plant communities, soil climatic features, water erosion, and hydrology. These groups are based in part on the *Keys to Soil Taxonomy, Seventh Edition* (Soil Survey Staff, 1996) and *Soil Taxonomy, A Basic System of Soil Classification for Making and Interpreting Soil Surveys*, Ag. Handbook 436 (Soil Survey Staff, 1975).

Table F lists the 11 site locations and groups them by soil orders, soil moisture regimes, soil temperature regimes, topsoil texture, subsoil texture, and other important soil features (master horizons and features that strongly influence soil behavior). Table C summarizes the information in this section. Table B lists the classification of the soil series found at all 11 site locations.

Soil features such as those found in Table F typically have a strong impact on use and management of a particular soil series or map unit. Frequently these features affect plant communities, available moisture, growing season, and plant metabolism. This subsection refers to the 11 site locations rather than the 26 sites, because within a given site location only one phase of a soil series occurs, but 2 or 3 different contrasting vegetation states were sampled and studied. Soil information within this section applies to all of the contrasting vegetative states studied on one soil series.

Soil Orders

Five of the eleven soil orders are found in the eleven NRST site locations. Four of the sites are found on Mollisols which typically have deep dark surface layers and higher organic matter content. Three of the sites are found on Aridisols which typically have arid or semi-arid moisture regimes, and very low organic matter content. Two of the sites are found on Vertisols, which typically exhibit deep cracks during the dry season and churning of the soil during the wet season. One site is found on an Alfisol which typically have deep surface layers that are not as dark as Mollisols and few other diagnostic features, but have higher organic matter content. One site is found on an Entisol with low organic matter content.

Soil Moisture Regimes

Moisture regimes directly affect water availability for plants. All of the moisture regimes except udic soils found on NRST sites, have some degree of moisture deficit during the growing season. Aridic is the driest. Ustic and Xeric being intermediate. Udic is not limiting to plant growth.

Aridic

Four of the eleven site locations occur in the aridic moisture regime. The aridic moisture regime is typically hot and dry with arid or semi-arid conditions. Within the aridic regime subdivisions can be made. Three of the NRST sites occur in the ustic aridic subdivision. Ustic aridic is moister than is common for the aridic regime. Typically it is semi-arid and borders on the ustic moisture regime which has dry cool winters and moist hot summers. One of the 11 site locations occurs in the xeric aridic subdivision. Xeric aridic is also more moist than is common for the aridic regime. Typically, it is semi-arid and borders on the xeric moisture regime, which has cool moist (Mediterranean) winters and warm dry summers.

Ustic

Two of the NRST 11 site locations are found in the Ustic moisture regime. Typically the ustic moisture regime is sub-humid and has hot moist summers and dry cool winters. This regime also can be subdivided. The aridic ustic subdivision is dry sub-humid and has dryer summers than is typical for ustic and borders on the aridic moisture regime.

Xeric
One of the 11 site locations is found in the Xeric moisture regime. This site falls within the typic xeric subdivision and has cool moist winters and warm dry summers. The xeric moisture regime is typical of Mediterranean climates.

Udic
Two of the NRST sites are found in Udic moisture regime. This regime is typical of humid climates with well distributed rainfall.

Borolls
Although not a moisture regime, this group is worth noting separately. These sites occur in cold climates. For these sites the soil moisture regime is less important than the temperature regime. Temperature is the most limiting factor for plant growth. However, both sites are within the Ustic moisture regime, when temperatures are high enough to support plant growth.

Soil Temperature Regimes
Mesic
The most common temperature regime for the 11 site locations is Mesic. Seven of the sites occur in this temperature regime. The mean annual soil temperature falls between 8 and 15°C. The Mesic regime has distinct warm summers and cool winters, with a difference of at least 5°C between them.

Thermic
The second most common temperature regime for the NRST sites is Thermic. Two of the 11 site locations occur in this temperature regime. The mean annual soil temperature falls between 15 and 22°C. The Thermic regime also has distinct hot summers and warm winters; with a difference of at least 5°C between them.

Cryic or Frigid
Two of the 11 site locations fall in the Cryic or Frigid temperature regime. These sites are usually cold or very cold. Typically these sites have cool or cold summers. They have a mean annual temperature between 0 and 8°C. A frigid site has warmer summers than a cryic one. For frigid sites the difference between summer and winter temperatures is at least 5°C.

Topsoil Texture
Topsoil texture affects the structure, tilth, water holding capacity, degree of crusting, and density of the surface layer which is the seedbed for germinating plants.

Six of the NRST site have soils with medium textured surface layers. Four are loams (7 to 27% clay and ≥15% sand). Two are silt loams (12 to 27% clay and <15% sand). Three of the 11 site locations have soils with moderately coarse textured surface layers. Three are sandy loams (<20% clay and >43% sand). Two of the NRST sites have soils with moderately fine or fine textured surface layers. One is a silty clay loam (27 to 40% clay and <15% sand). One is silty clay (40 to 60% clay and <15% sand) or clay loam (27 to 40% clay).

Subsoil Texture
Particle-size Control Section
(For the NRST soils, the particle-size control section falls between 10 and 40 inches, or within the argillic horizon)

Texture of the subsoil affects structure, water holding capacity, density, water transmission rate, pore size distribution, and nutrient availability in the root zone.

Five of the NRST sites are fine-loamy in the particle-size control section. Fine-Loamy soils have ≥15% sand and 18-35% clay. Four of the 11 site locations are fine in the particle-size control section. Fine soils have 35-60% clay. One of the 11 site locations is coarse-loamy in the particle-size control section. Coarse-loamy soils have ≥ 15% sand, and <18% clay. One of the NRST sites is fine-silty in the particle-size control section. Fine-silty soils have <15% sand and 18-35% clay.

Other Important Soil Features

The soils occurring on NRST sites have some additional features that affect water availability and plant growth.

Argillic Horizon

Four of the 11 site locations have soils with argillic horizons. These sites have subsoils with significantly more clay than the overlying topsoil.

Lime (Calcium carbonates)

Nine of NRST site locations have soils containing significant amounts of calcium carbonate or lime. Two of sites have soils with well developed calcic horizons. Calcic horizons contain >15% $CaCO_3$ equivalent, and they have ≥5% more carbonates than the underlying substratum for soils having ≥18% clay. Calcic horizons contain >5% more carbonates than the underlying substratum for soils having <18% clay. Typically, calcic horizons occur in sub-humid to arid soils where a moisture deficit occurs during part of the year. Precipitation seldom wets the whole soil, and lime is precipitated out when the moisture is used by plants and/or evaporated. This is a common condition for rangeland soils. Lime affects water and nutrient availability for plants.

Calcium carbonate or lime accumulations occur in the soils on six of the 11 site locations. Although less significant than the calcic horizons described above, lime strongly influences the behavior of these soils. These soils, like those with calcic horizons, also experience a moisture deficit, and lime is precipitated in the soil in the same manner.

One NRST site has a soil where calcium carbonate or lime occurs throughout. These soils also experience periods of moisture deficit as described above. However, these soils are recharged with lime from air-borne dust, which keeps the amount of lime at a relatively constant level throughout the soil.

Two of the 11 site locations have soils with no significant calcium carbonate or lime accumulations. This situation occurs in soils where the parent material has little or no carbonates and/or precipitation is high enough to leach carbonates from the soil.

TABLE F. Pertinent Soil Features. This table groups NRST sites by soil features that affect use and management of both the soil and plant community.

Site	B	C	E	F	G	H	I	J	K	L	M
State	NE	TX	KS	CO	WY	ND	WY	ID	AZ	CA	UT
Range Site	Silty	Deep Hardland	Loamy Upland	Loamy Plains	Loamy	Sandy	Loamy	Loamy 16-22	Loamy Upland	Clayey	Semidesert Loam
Soil Name	Burchard	Olton	Martin	Stoneham	Kishona	Parshall	Forkwood	Robin	Lonti	Diablo	Taylors Flat
Soil Order											
Mollisols	X	X				X		X			
Aridisols							X		X		X
Vertisols			X							X	
Alfisols				X							
Entisols					X						
Moisture Regime											
Aridic											
Ustic Aridic					X		X		X		
Xeric Aridic											X
Ustic											
Aridic Ustic		X		X							
Xeric										X	
Udic	X		X								
Borolls*						X		X			
Temperature Regimes											
Mesic	X		X	X	X		X		X		
Thermic		X								X	
Cryic or Frigid						X		X			
Topsoil Texture											
Medium	X	X		X	X						
moderately coarse						X			X		X
moderately fine or fine			X							X	

TABLE F contintued

Site	B	C	E	F	G	H	I	J	K	L	M
State	NE	TX	KS	CO	WY	ND	WY	ID	AZ	CA	UT
Range Site	Silty	Deep Hardland	Loamy Upland	Loamy Plains	Loamy	Sandy	Loamy	Loamy 16-22	Loamy Upland	Clayey	Semidesert Loam
Soil Name	Burchard	Olton	Martin	Stoneham	Kishona	Parshall	Forkwood	Robin	Lonti	Diablo	Taylors Flat
Subsoil Texture (Particle-size Control Section)											
fine-loamy	X			X	X		X				X
fine		X	X						X	X	
coarse-loamy						X					
fine-silty								X			
Other Important Features											
Argillic horizons	X	X					X		X		
Calcic horizons		X									X
lime accumulation	X			X		X	X		X	X	
lime throughout					X						
no lime			X					X			

*Borolls - Although not a moisture regime, are noted here because the cold climate is considered more important than the moisture regime.

V. Site Selection and Study Design

Introduction

The hydrology and erosion data were obtained from rainfall simulation studies similar to the 1987-88 WEPP study (Lane and Nearing, 1989). The criteria for site selection included sites that represented benchmark soils and rangeland community types with known management history. (A benchmark is a standard or point of reference in measuring or judging specific quality and value.) The NRST was concerned about addressing applicable nationwide concerns through careful site selection

To examine and quantify vegetation-soil-hydrology interactions, two or three contrasting vegetation states were chosen that were of interest and relevant to the area and to management of the selected and similar ecological sites, rangeland cover types, and soils. All of the sites were on native rangeland with no indication of tillage.

The rangeland cover type terms used are taken from the Society for Range Management's 1994 publication "Rangeland Cover Types of the United States" (Shiflet, 1994). The sites also were chosen to have uniform soil properties (i.e., the same phase of a soil series) and similar potential natural vegetation. Present vegetation differences were assumed to have resulted from past and current site management. Some of the main characteristics evaluated to identify contrasting vegetation states were significant differences in plant species composition, biomass production, ground cover, and litter. Characteristics selected to evaluate changes in the soil surface conditions associated with plant community differences were bulk density, root biomass, aggregate stability, and moisture content.

Site Selection

Sites were selected based on the Benchmark Site concept (Franks et al., 1993). Benchmark sites represent an integrated approach which encompasses the following three components, benchmark plant community, representative or benchmark soil, and known management history. This approach greatly enhances the utility of site data by tying it to representative sites which apply to larger areas within a given geographic location, through the use of NRCS soil survey reports, Major Land Resource Area maps, and reports and databases.

Site selection also considered access and cooperation of the land owner or manager. At each potential study site, 22 soil pedons around the perimeter were briefly examined. If these pedons were sufficiently similar in characteristics that effect hydrologic behavior of the soil (i.e., within the same phase), the potential study site was deemed suitable. If the pedons were not sufficiently similar, the boundaries of the potential study site were adjusted and additional pedons were described. This process was reiterated until a suitable study site was located. Plots to receive rainfall simulation and vegetation sampling were located uniformly (in pairs) within the study site. Study sites were located on slopes between 3 and 12%.

Basic Study Design

A total of 26 individual rangeland sites, at 11 locations, in 10 western states, were investigated between 1990-1993. At every site, a suite of hydrologic, vegetation, and soils information was collected. The study design was to measure properties that were uniform within an individual site but may vary between individual sites (2 or 3) within a site location (11 total) and that may vary during the course of rainfall simulation on a plot. The information collected would be used to develop, calibrate, and validate the Water Erosion Prediction Project (WEPP) model. The information also could be used directly to evaluate management options for the investigated and similar sites. Although sampling was conducted as designed, not all measures are available on all large or small plots at all study sites.

Site Level Soil Properties

At each site, 22 pedons around the perimeter of the site (forming a rectangle with a transect on each side) were briefly examined and described morphologically to a depth of 0.5 m at 7.6 m intervals. If soil characterization sampling occurred prior to rainfall simulation, five pedons from the 22 perimeter pedons were selected for detailed description and sampled for complete characterization by NRCS's National Soil Survey Laboratory.

If characterization sampling occurred after rainfall simulation, five of the six plots were selected for sampling. Of the five, one pedon was chosen to be most representative of the soil phase at the site (see Tables 1 and 2 of each state summary). The representative pedon was sampled and characterized to a depth of 1.5 meters. The other four pedons (satellite pedons) were selected to represent proportionately dominant and minor near surface soil conditions occurring at the site.

The satellite pedons were sampled and characterized to a minimum depth of about 0.5 meters (always to the bottom of the upper 2 master horizons). This pedon characterization included detailed particle-size distribution, soil fabric, cation exchange capacity, soluble salts, organic carbon, soil chemistry, mineralogy, and soil water characteristics analyses. Aggregate stability was also determined on the surface horizons of the 5 pedons sampled (See Soils section of each state summary). Laboratory procedures are given in detail in the Soil Survey Laboratory Methods Manual (USDA, NRCS, 1996).

Additional study site level measurements that were made include detailed physical and mechanical analyses by NRCS's National Soil Mechanics Laboratory of soil samples collected at the site. These analyses were Atterberg Limits, Unconfined Compressive Strength, Direct Shear Strength at Low Confining Pressure, Pin-hole Dispersion, and Middleton Dispersion Ratio.

VI. Data Collection and Measurement Methods

Plot Level Soil Properties

Soil bulk density was determined using either the compliant cavity or balloon bulk density method (both excavation methods). Bulk density determinations were made before the dry run and after the very wet run. A minimum of six locations outside the plot, but in the buffer strip within the rainfall simulation area, were selected randomly and sampled. (Twelve were sampled if there was a distinct pattern of plant canopy cover and interspaces; i.e., 6 randomly chosen bare areas and 6 vegetated areas either under shrub or grass canopy or in interspaces between the vegetation). At each sampled location, bulk density determinations were made at two depths, 0-2.5 cm and 2.5-10 cm below the soil surface (see Table 3 of each state summary).

Gravimetric soil moisture was determined within 30 minutes before the dry run rainfall simulation, 30 minutes before the wet run, 30 minutes after the wet run, and 30 minutes after the very wet run. For each sampling period, 6 samples were collected for each large plot within the buffer area which received rainfall but was not disturbed by foot or vehicle traffic. Three samples were collected for 0-5 cm depth at the relative top, middle, and bottom position of the plot. Three samples were collected in the 5-20 cm depth or to the depth of the wetting front, if it was not 20 cm deep. On each small plot, only a single sample was collected at each depth (0-5 cm and 5-20 cm) following rainfall simulation.

Plot Level Vegetation Properties

Canopy and ground cover was measured on all large and small plots, using a point-frequency-frame (see Table 4 of each state summary). The large plots were sampled using 10 transects of a 49-pin frame, and the small plots sampled using 6 transects of an 11-pin frame. For both the small and large plots, the first plant material encountered as the pin was lowered to the ground was recorded as being shrub, half-shrub, forb, grass, cactus, or standing dead (of any of the preceding categories). If no plant material was encountered until the ground surface or its covering, then no canopy pin-hit was recorded. For both the small and large plots, ground surface cover was recorded as being a cryptogram <1 cm diameter, cryptogram >1 cm diameter, bare ground (mineral aggregates <2 mm diameter), rock (mineral aggregates >2 mm diameter), litter, or basal vegetation. In addition, ground surface height above an arbitrary reference line was recorded for each pin. The standard deviation of heights was determined for each transect. For each plot, the surface random roughness was calculated as the average of the standard deviations on each transect across the plot. Measurements of distance to the nearest plant, its life form from the list above for canopy, and its height and diameter were made in each of 4 quadrants centered about the 25th pin of each transect at sites sampled in 1990 and 1991 and of odd-numbered transects in 1992 and 1993. In 1992 and 1993, the height and diameter of each plant in each quadrant also was measured.

The annual yield by species, dead standing biomass, and other organic biomass (manure) was determined on each large plot during the course of plant community assessments (see Table 5 of each state summary). Total Standing biomass by life-form category was determined on small plots by clipping, oven drying, and weighing.

Below-ground root biomass within the upper 10 cm of soil was determined using a modification of the surficial soil vegetal material method (R. B. Grossman, unpublished). Soil cores were collected and, after removal of the surface vegetation, were dried and later wet sieved to remove all the mineral soil. The remaining root sample was re-dried to determine below ground biomass (see Table 6 of each state summary).

Plant height and density, and canopy diameter and geometric shape, were measured for plants along 4 transects at some sites. The beginning of each 30-meter transect was located at 2, 7, 23, and 28 meters from the right side of the plot and 10 meters from the top of the site. In sod-forming grass and forb-dominated plant communities, measurements were taken at 0.3-meter intervals. In bunch grass- and shrub-dominated plant communities with irregularly distributed vegetation, measurements were taken at 1.5-meter intervals.

Rainfall Simulation

Rainfall simulation using a rotating-boom rainfall simulator (Swanson, 1965) was conducted at all sites. The rotating-boom rainfall simulator applied simulated rainfall simultaneously to 2 large (10 feet by 35 feet) and 2 small (2 feet by 4 feet) experimental plots. The large plots were not treated in any way, so that all simulation and measurements were conducted on 'natural' plots. Prior to rainfall, all standing vegetation was clipped and removed from the small plots.

A sequence of rainfall simulation plot-runs were conducted on each plot. The first plot-run was conducted at initial soil saturation and was called the "dry run." The dry run typically lasted an hour or until steady state runoff is achieved. The next plot-run was conducted approximately 24 hours after the dry run and was called the "wet run." This run typically lasted half an hour and used the same target rainfall intensity as the dry run. Thirty minutes after the wet run, another run was conducted-the "very wet plot-run." The very wet plot-run begins with an interval of rainfall intensity the same as the dry and wet run. When steady state runoff was achieved, the rainfall intensity was doubled and maintained until a new steady state runoff was achieved. Finally, the rainfall intensity was lowered to the initial rate and once again maintained until steady state runoff was achieved.

Besides measures of rainfall, runoff, and sediment yield on each large and small plot, wind speed and direction, air and water temperature, time to 50% ponding, and time to beginning and ending of observable runoff also were measured. The measured properties were used to calculate or derive additional values (see Table 7 of each state summary). Total rainfall, total runoff, and total sediment yield were the cumulative values from the beginning of rainfall simulation to the end of observed runoff. The uniform rainfall rate was the average rainfall intensity during the simulation (total rainfall divided by rainfall duration). Because of the variation in rainfall rate during the very wet plot-run, a uniform rainfall rate was not calculated. Runoff to rainfall ratio (total runoff divided by total rainfall) was a useful value when rainfall duration was not uniform between study sites or plots within a site. Sediment yield to runoff ratio (total sediment yield divided by total runoff) was a useful value when total runoff was not similar between study sites or plots within a site. These ratios provide additional information useful in making comparisons between study sites and plot-runs.

Initial abstraction was the amount of rainfall that falls before runoff was observed. It combines interception by vegetation and litter and storage in depressions but also contains infiltration and overland flow. Although these components cannot be separated, initial abstraction was still useful in making comparisons between study sites and plot-runs. Recession depth was the runoff observed after the cessation of rainfall simulation. Similarly to initial abstraction, it combines several components but was still useful for making comparisons. The equilibrium infiltration rate was the difference between rainfall rate and runoff rate when steady state runoff was achieved. Since steady state runoff was not always achieved, it was not always possible to calculate an equilibrium infiltration rate. Also, although equilibrium infiltration rate was calculated for each period of the very wet run, it was not reported because there would be three values instead of the one for all the other measures see (Table 7 of each state summary). Additional values may be of interest and useful for specific analyses and can be calculated and/or derived from the basic information available.

STATE DATA SUMMARIES

NRST rangeland sites in Arizona

Site Descriptions

Two study sites, **K1** and **K2**, were sampled in Yavapai County, Arizona during September, 1992. Study sites **K1** (SW ¼ of SE ¼ of S12 T17N R4W, 34° 46′ 41″ N, 112° 37′ 57″ W) and **K2** (SW ¼ of SE ¼ of S12 T17N R4W, 34° 46′ 37″ N, 112° 37′ 54″ W) were located approximately 18 miles NW of Prescott, AZ, on private land leased for grazing. The two study sites were less than ¼ mile apart. The relevant Soil and Water Conservation District (SWCD) is Chino Hills. The relevant NRCS office is the Prescott Field Office. The Major Land Resource Area is Colorado and Green River Plateaus (MLRA No. 35) of the Western Range and Irrigated Region. Approximately 90% of this MLRA is rangeland (USDA, SCS, 1981). The dominant vegetation is desert shrub and woodland. At higher elevations, pinyon-juniper woodlands and sagebrush have an understory of galleta (*Pleuraphis jamesii* Torr.), blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths), black grama (*Bouteloua eriopoda* (Torr.) Torr.), and western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love) (USDA, SCS, 1981).

The range cover type for study sites **K1** and **K2** is Grama-Galleta of the Southwestern Region. Blue grama is the usually the dominant species, with galleta as an important secondary species (Pieper, 1994). Normally big sagebrush (*Artemisia tridentata* Nutt.) is not a component of this range cover type. Its occurrence is likely a result of disturbance (Pieper, 1994).

The range site is **Loamy Upland**. This range site occurs in upland positions on gently rolling plains, fans, and terraces. The soils of this range site are moderately deep to very deep, well drained, and form in mixed alluvium and in place from weathered schist, granite, basalt, and sandstone (USDA, SCS, 1982b). The historic climax plant community would be dominated by short-and mid-grasses and shrubs. Important species would include the grasses black grama, sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), blue grama and hairy grama (*Bouteloua hirsuta* Lag.) and the shrubs desert ceonothus and birchleaf mountain mahogany. The potential average annual production during normal years is 650 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 500 pounds per acre or less and, in favorable years, annual productions can reach 850 pounds per acre (USDA, SCS, 1982b).

Study sites, **K1** and **K2**, were selected to represent two contrasting vegetation states in the Grama-Galetta Range Cover Type of the Southwestern Region. Study site **K1** was dominated by grasses, with blue grama being the most common on the site, followed by ring muhly (*Muhlenbergia torreyi* Kunth), with lesser amounts of sand dropseed (*Sporobolus cryptandrus* Torr.) and threeawn (*Aristida* L.). Site **K1** had no significant shrub canopy, but study site **K2** appeared to have significant canopy cover from shrubs. Study site **K2** was dominated by rubber rabbitbrush (*Chrysothamnus nauseosus* ssp. *nauseosus* Pallas ex Pursh) along with a strong component of blue grama grass. Both sites **K1** and **K2** had similar amounts of bare soils, but site **K2** had significantly more mulch (litter) on the soil surface than site **K1**.

Climate

The rapidly changing topography and elevation of the area in which the study sites are located makes description of climate from nearby stations less precise than in other states. Information for both Prescott and Chino Valley follow: The average annual precipitation is 18.39 inches at Prescott, AZ. The average annual snowfall is 26.2 inches. July is the hottest month, with an average maximum temperature of 88.8 °F. January is the coldest month, with an average minimum temperature of 20.9 °F (WRCC, 1997d). The average annual precipitation at Chino Valley, approximately 10 miles WNW of study sites **K1** and **K2**, is 12.72 inches. July is the hottest month, with an average maximum temperature of 92.3 °F. December is the coldest month, with an average minimum temperature of 21.3 °F (WRCC, 1997c). The climate at Chino Valley is probably more representative than Prescott for the two sampled study sites.

Soils

Soils at both study sites are correlated with the Lonti series. The site is mapped as the Lonti-Wineg complex, 3 to 15 percent slopes. This map unit association is comprised of the Lonti gravelly sandy loam and the Wineg sandy loam. These soils form in an intricate pattern on undulating to rolling plains that are dissected by a few long drainageways and many short drainageways that have steeply sloping sides. (USDA, SCS, 1976). These soils are classified as a fine, mixed, mesic Ustic Haplargids. The **NSSL** pedon numbers for the representative soil pedon at each study site are 92P0058 and 92P0063 for study sites **K1** and **K2**, respectively. Some selected soil chemical and physical properties are presented in Tables 1a, 1b, 2a, and 2b for study sites **K1** and **K2** in Arizona.

Bulk density was sampled on six plots at each study site, using an excavation method (either the compliant cavity or the balloon method). Bulk density was measured at three positions and two depths, before and after rainfall simulation. Table 3 present the field measured, plot-average bulk density determined at study sites **K1** and **K2**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **K1** were **22.2%** and **11.1%**, respectively. The respective values at study site **K2** were **9.4%** and **14.8%**.

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 93P0058 at study site **K1** in Arizona.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-10	FSL	53.0	36.7	10.3	-.-- 1/	9
Bt1	10-16	L	46.1	39.9	14.0	1.48	9
Bt2	16-44	CL	31.9	40.3	27.8	1.56	7
Bt3	44-78	L	33.7	41.4	24.9	-.--	4
2Bt	78-96	CL	34.0	38.4	27.6	-.--	6
2Btk	96-142	L	41.7	33.2	25.1	1.79	7
3Bk	142-200	SIL	15.7	62.7	21.6	-.--	Tr 2/

1/ measure not taken on sample

2/ Tr = Trace Amount

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 93P0063 at study site **K2** in Arizona.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-8	FSL	56.4	37.0	6.6	-.--	10
Bt1	8-40	CL	36.9	34.7	28.4	1.60	6
Bt2	40-59	L	38.3	40.7	21.0	1.56	7
Bt3	59-105	L	50.5	28.8	20.7	1.67	6
Btk	105-155	L	43.4	37.4	19.2	1.81	7
2Btk	155-200	SIL	26.7	51.6	21.7	-.--	3

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 93P0058 at study site **K1** in Arizona.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-10	1.26	0.11	Tr	10.3	6.1
Bt1	10-16	0.55	0.02	0.17	11.3	6.2
Bt2	16-44	0.54	0.02	0.12	20.1	7.2
Bt3	44-78	0.43	Tr	Tr	18.8	7.6
2Bt	78-96	0.28	Tr	Tr	20.6	7.6
2Btk	96-142	0.17	Tr	0.11	19.6	8.0
3Bk	142-200	0.13	-.--	Tr	20.1	7.8

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 93P0063 at study site **K2** in Arizona.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-8	0.72	0.03	Tr	7.2	5.4
Bt1	8-40	0.60	0.01	0.10	20.2	7.1
Bt2	40-59	0.45	Tr	0.11	16.2	7.4
Bt3	59-105	0.16	Tr	0.12	16.4	7.9
Btk	105-155	0.10	Tr	0.08	17.3	8.0
2Btk	155-200	0.12	Tr	Tr	23.8	7.8

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) sampled by compliant cavity method for sites in Arizona.

Sample time and depth	Site K1	Site K2
before dry run, 0-1"	1.07	0.74
before dry run, 1-4"	1.46	1.27
before dry run, 0-4" (weighted average)	1.36	1.14
after very wet run, 0-1"	1.17	0.94
after very wet run, 1-4"	1.40	1.23
after very wet run, 0-4" (weighted average	1.34	1.16

Management History

Both study sites are in the same 560-acre pasture. The study sites are grazed from May to November. The pasture was "knifed" over 20 years ago. No additional detail is available to describe this mechanical treatment. One or both of these sites were effected by this treatment. Although grass cover and biomass are similar between the study sites the shrub cover and biomass are substantially higher at study site **K2** than **K1**. These differences are assumed to be due to past management actions.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. The study site plot-average is presented in Table 4. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Their plot-average values are presented in Table 5. Only the current year's leaves of rubber rabbitbrush (*Chrysothamnus nauseosus* ssp. *nauseosus* (Pallas ex Pursh) Britt.) were used for annual production. Total standing biomass of previous year's leaves were included in the standing-live wood category.

Below ground root biomass was also measured for all plots at each study site. Areas in plant interspaces and under plant canopies were sampled separately at study site **K2**. At study site **K1,** a relatively uniformly spaced plant community with no interspaces was present, therefore only a single type of surface area was sampled. The surface, sub-surface, and total plot-averaged values for each study site and surface type are presented in Table 6.

Table 4. Canopy and ground cover (%) for study sites in Arizona.

Cover category	Site K1	Site K2
Grass	31.2	34.6
Forb	14.6	4.5
Shrub	1.2	10.2
Cactus	0.2	0.0
Half-Shrub	0.2	0.4
Standing Dead	0.6	1.3
Total canopy cover	**48.0**	**51.1**
Basal vegetation	15.4	18.2
Cryptogam <1cm	0.0	0.0
Cryptogam >1cm	0.0	0.1
Litter	28.7	26.0
Rock	5.1	5.9
Bare soil	50.7	49.8
Total ground cover	**49.3**	**50.2**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Arizona sites. Value of 0.0 denotes absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site K1	Site K2
Native grasses and sedges		
blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)	277.1	547.3
ring muhly (*Muhlenbergia torreyi* (Kunth) A.S. Hitchc. ex Bush)	118.6	1.8
threeawn (*Aristida* L.)	56.3	51.5
sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray)	55.5	7.5
black grama (*Bouteloua eriopoda* (Torr.) Torr.)	21.6	0.0
false buffalograss (*Monroa squarrosa* (Nutt.) Torr.)	2.1	0.0
sixweeks fescue (*Vulpia octoflora* var. *octoflora* (Walt.) Rydb.)	1.0	1.3
bottlebrush squirreltail (*Elymus elymoides* (Raf.) Swezey)	0.5	9.0
sixweeks grama (*Bouteloua barbata* Lag.)	0.0	1.8
Total of native grasses and sedges	**533.0**	**620.3**
Native forbs and other herbaceous plants		
alkali goldenbush (*socoma acradenia* var. *eremophila* (Greene, Nesom)	145.1	14.6
globemallow (*Sphaeralcea* St.-Hil.)	3.1	1.1
rose heath (*Chaetopappa ericoides* (Torr.) Nesom)	2.6	16.0
groundcherry (*Physalis* L.)	0.3	0.0
woolly plantain (*Plantago patagonica* Jacq.)	0.0	Tr
fleabane (*Erigeron* L.)	0.0	23.3
spurge (*Euphorbia* L.)	0.0	1.0
sunflower (*Helianthus* L.)	0.0	0.1
plantain (*Plantago* L.)	0.0	Tr
goatsbeard (*Tragopogon* L.)	0.0	1.3
eriogonum (*Eriogonum* Michx.)	Tr	Tr
Total of native forbs and other herbaceous plants	**151.3**	**57.6**
Native shrubs and cacti		
broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby)	3.3	4.6
rubber rabbitbrush (*Chrysothamnus nauseosus* ssp. *nauseosus* (Pallas ex Pursh) Britt.)	0.0	476.3
Total of native shrubs and cacti	**3.3**	**481.0**
Introduced grasses		
cheatgrass (*Bromus tectorum* L.)	23.1	Tr
brome (*Bromus* L.)	1.3	0.0
lovegrass (*Eragrostis* von Wolf)	1.0	0.0
Total of introduced grasses	**25.5**	**0.0**

Table 5 continued

Introduced forbs and other herbaceous plants		
redstem stork's bill (*Erodium cicutarium* (L.) L'Her. ex Ait.)	65.6	Tr
Russian thistle (*Salsola* L.)	3.1	Tr
Total of introduced forbs and other herbaceous plants	**68.8**	**Tr**
Total average live plant annual yield	**782.0**	**1159.0**
Soil surface residue and standing dead plant material		
manure	877.0	42.8
non-woody litter	216.1	735.1
woody litter	50.0	85.6
standing-dead grass	38.1	28.3
standing-live wood	0.0	1052.3
Total of soil surface residue and standing dead plant material	**1181.3**	**1944.3**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Arizona.

	Under Plant Canopy [1/]		**Plant Interspace** [2/]	
Sample depth	**Site K1**	**Site K2**	**Site K1**	**Site K2**
0-1"	1776.3	1286.6		1795.1
1-4"	494.0	474.9		656.3
0-4" (total)	2270.3	1761.5		2451.4

1/ Samples taken in area under plant canopies.
2/ Samples taken in open areas not under plant canopies.

Hydrology

Only 34 of the possible 36 plot-runs were useable for study sites **K1** and **K2**. The headwall, that part of the plot that forms the lower boundary and provides contact between the soil and the runoff troughs, of plot 3 at study site **K1** severely leaked during the wet plot-run and completely failed during the very wet plot-run. Because of this, the plot-runs were abandoned and were not included in any analyses. Measured sediment concentrations during the very wet plot-run of plot 5 at study site **K2** appeared to be too high, although runoff appeared normal. There was no correction that could be applied. For this report, this plot-run has had total sediment yield and sediment yield to runoff ratio excluded from calculations of averages for the study site. This has the effect of reducing the average total sediment yield of the very wet plot-runs at study site **K2** by over 50%.

Table 7. Hydrology Results for study sites in Arizona. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site K1	Site K2
Dry plot-runs at antecedent soil moisture		
Total rainfall (mm)	55.50	55.56
Uniform rainfall rate (mm h^{-1})	55.50	55.56
Rainfall duration (minutes)	60.00	60.00
Total runoff (mm)	12.72	17.51
Runoff to rainfall ratio (mm mm^{-1})	0.23	0.31
Time to start of runoff (minutes)	7.71	6.71
Peak runoff rate (mm h^{-1})	20.49	25.02
Time to peak runoff (minutes)	35.83	44.67
Initial abstraction depth (mm)	7.50	6.79
Recession depth (mm)	0.55	0.79
Total sediment yield (kg ha^{-1})	195.71	158.56
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	11.52	9.48
Equilibrium infiltration rate (mm h^{-1})	36.58	32.81
Wet plot-runs 24 h after dry plot-runs		
Total rainfall (mm)	27.93	27.00
Uniform rainfall rate (mm h^{-1})	57.36	59.28
Rainfall duration (minutes)	29.20	27.33
Total runoff (mm)	10.25	9.78
Runoff to rainfall ratio (mm mm^{-1})	0.36	0.36
Time to start of runoff (minutes)	4.85	4.48
Peak runoff rate (mm h^{-1})	33.82	34.99
Time to peak runoff (minutes)	22.20	22.50
Initial abstraction depth (mm)	5.36	4.94
Recession depth (mm)	1.14	1.23
Total sediment yield (kg ha^{-1})	75.34	100.55
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	7.24	10.04
Equilibrium infiltration rate (mm h^{-1})	26.51	26.88
Very wet plot-runs 30 minutes after wet plot-runs		
Total rainfall (mm)	72.97	69.83
Rainfall duration (minutes)	55.20	54.00
Total runoff (mm)	39.65	41.09
Runoff to rainfall ratio (mm mm^{-1})	0.54	0.59
Time to start of runoff (minutes)	2.98	2.81
Peak runoff rate (mm h^{-1})	91.51	92.06
Time to peak runoff (minutes)	33.00	29.17
Initial abstraction depth (mm)	3.45	3.46
Recession depth (mm)	1.07	1.36
Total sediment yield (kg ha^{-1})	315.48	537.21
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	7.70	13.55

NRST Rangeland Sites in California

Site Descriptions

Two annual grassland sites, **L1** and **L2**, were sampled in San Luis Obispo County, California during April and May, 1993. Site **L1** (SE ¼ of NW ¼ of S9 T30S R12E, 35° 19′ 46″ N, 120° 41′ 49″ W) was on Camp San Luis Obispo, administered by the California National Guard. Site **L2** (SE ¼ of NE ¼ of S1 T30S R11E, 35° 20′ 40″ N, 120° 44′ 32″ W) was on an experimental watershed administered by California Polytechnic State University. Both sites were on the outskirts of San Luis Obispo, CA. The following descriptions apply to both sites unless noted otherwise. The relevant NRCS offices are the Morro Bay field office and the Salinas area office. The Soil and Water Conservation District is the Coastal San Luis RCD. The Major Land Resource Area (MLRA No. 15) is the Central California Coast Range in the California Subtropical Fruit, Truck, and Specialty Crop Region. Slightly more than 50% of this MLRA is comprised of grasses and shrubs and is used for range (USDA, SCS, 1981). Naturalized annuals such as soft chess (*Bromus hordeaceus* L.), bromes (*Bromus* L.), fescues (*Festuca* L.), wild oats (*Avena* L.), and forbs such as filaree (*Erodium* L'Her. ex Ait.) and burclover (*Medicago polymorpha* L.) comprise a large percentage of the species composition (USDA, SCS, 1981).

The range cover type is Valley Grassland of the Pacific Southwest Region. The native, perennial bunchgrasses of this region were replaced by introduced annual grasses in the late 18th and early 19th century, following the introduction of livestock grazing. Changes in livestock grazing have relatively little effect on successional patterns, compared to the fluctuations in plant species composition and productivity that result from variations in annual precipitation and temperature patterns. Plant species from the grass genera *Avena*, *Bromus*, *Festuca*, and *Hordeum* and annual forbs from the genera *Erodium*, *Trifolium*, *Madia*, *Amsinckia*, and *Brassica* are characteristic of the Valley Grassland range cover type (Bartolome and Brown, 1994).

The range site is **Clayey**. The potential average annual production during normal years is 5400 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 4000 pounds per acre or less and, in favorable years, annual productions can reach 6700 pounds per acre (USDA, SCS, 1984a).

Study sites **L1** and **L2** were selected to represent two contrasting vegetation states relevant to the Valley Grasslands range cover type. The two main criteria looked at in the annual grassland sites were the amount of bare soil and soil surface residue. Study site **L1** had a significant amount of bare soil and very little soil surface residue, although it did have significant canopy cover when considering the forbs on the site. Study site **L2** had a very small amount of bare soil and a significant amount of soil surface residue. Study site **L2** was dominated by annual grasses, whereas study site **L1** appeared to be dominated by a fairly equal mixture of forbs and annual grasses.

Climate

The climate is typically Mediterranean, with cool, moist winters, and dry, warm summers. The average annual precipitation is 21.5 inches. Three-fourths of the annual total precipitation occurs from December through March. Average annual air temperature is 58-60 °F. The coolest month is January, with an average daily minimum of 42 °F. The warmest month is September, with an average daily maximum of 78 °F (USDA, SCS 1984b).

Soils

Soils at both study sites were in the Diablo series. They are mapped as Diablo clay and may be mapped separately or included in Lodo clay loam mapping units. The Diablo series is classified as a fine, smectitic, thermic Typic Haploxererts. Diablo clays are deep, well drained, slowly permeable, and formed in weathered residual material of sandstone, shale, or mudstone (USDA, SCS, 1984b). The soil mapping unit for study site **L1** is Lodo clay loam, 5 to 15 percent slopes (USDA, SCS, 1984b). This unit includes small areas of Cibo clay, Diablo clay, Gazos clay loam, and Los Osos loam. The soil mapping unit for site **L2** is Diablo clay, 5 to 9 percent slopes (USDA, SCS, 1984b). Small areas of Cropley clay occur in concave positions in this mapping unit. The NSSL pedon numbers for the representative pedons sampled at study sites **L1** and **L2** are 93P0666 and 93P0661, respectively. Tables 1a, 1b, 2a, and 2 present some selected soil properties for study sites **L1** and **L2**.

Bulk density was sampled on six plots at each study site, using the balloon excavation method. Bulk density was measured at three positions and two depths before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **L1** and **L2**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **L1** were **69.3%** and **8.5%**, respectively. The respective values at study site **L2** were **78.8%** and **6.0%**.

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 93P0666 at study site **L1** in California.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-3	CL	33.7	29.8	36.5	-.-- 1/	14
Bw1	3-13	CL	32.0	29.0	39.0	1.91	1
Bw2	13-42	C	31.7	27.9	40.4	1.89	Tr
Bss1	42-72	C	31.3	28.5	40.2	1.97	2
Bss2	72-84	CL	31.6	28.5	39.9	1.94	3
Bkss	84-96	CL	32.0	28.9	39.1	1.80	Tr
BCk	96-115	CL	32.5	32.7	34.8	-.--	4
Cr	115-150	L	28.0	46.2	25.8	-.--	Tr 2/

1/ measure not taken on sample

2/ Tr = Trace Amount

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 93P0661 at study site **L2** in California.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-4	SIC	15.9	42.2	41.9	1.68	2
A2	4-20	SIC	14.8	41.3	43.9	1.87	1
Bss1	20-53	C	17.2	39.3	43.5	1.91	1
Bss2	53-69	C	16.9	39.4	43.7	1.95	2
BCkss	69-80	SIC	16.4	40.7	42.9	1.96	9
Ck	80-117	SICL	11.0	50.8	38.2	2.00	4
Cr	117-150	SICL	9.4	56.0	34.6	-.--	85

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 93P0666 at site **L1** in California.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-3	2.27	0.22	Tr	38.6	6.9
Bw1	3-13	1.38	0.15	0.12	41.6	7.1
Bw2	13-42	0.89	0.10	0.13	42.7	7.5
Bss1	42-72	0.72	0.08	0.09	42.0	8.1
Bss2	72-84	0.64	0.06	0.10	41.7	8.4
Bkss	84-96	0.55	-.--	0.07	37.0	8.6
BCk	96-115	0.40	-.--	Tr	27.6	8.7
Cr	115-150	-.--	-.--	Tr	22.5	8.6

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 93P0661 at study site **L2** in California.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-4	2.89	0.27	0.10	36.0	6.2
A2	4-20	1.73	0.18	0.11	37.0	6.6
Bss1	20-53	1.13	0.13	0.09	32.6	8.2
Bss2	53-69	0.98	0.10	0.10	29.2	8.6
BCkss	69-80	0.75	0.10	0.08	25.0	8.9
Ck	80-117	0.32	-.--	0.07	16.5	9.1
Cr	117-150	-.--	-.--	Tr	17.5	8.7

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in California.

Sample time and depth	**Site L1**	**Site L2**
before dry run, 0-1"	1.05	1.12
before dry run, 1-4"	1.51	1.42
before dry run, 0-4" (weighted average)	1.39	1.35
after very wet run, 0-1"	1.08	0.92
after very wet run, 1-4"	1.36	1.41
after very wet run, 0-4" (weighted average)	1.29	1.29

Management History

Study site **L1** is leased for grazing. Grazing is by cow and calf and is yearlong. The area is not fenced and is considered open-range. The site is described as currently heavily grazed. This area has been grazed continuously since 1870 except during 1941-1946. There have been no range treatments applied and there is no record of the study site having ever burned. Study site **L2** is operated as an experimental, grazed watershed by California Polytechnic. The area sampled is within a 300-acre pasture that was fenced in 1968. This pasture is grazed by steers and replacement heifers typically from November to May (winter and spring). Use is approximately 350 animal unit months per year. The actual sampling occurred in an area (125 feet by 350 feet) that was fenced with electrical wire just prior to sampling. Eleven head of cattle were allowed to graze in the fenced area for 7 days before sampling. This treatment was designed to reduce green cover to approximately 50 percent by weight.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values.

Below ground root biomass also was measured for all plots at each study site. A relatively uniformly spaced plant community with no interspaces was present at the sites; therefore, only a single type of representative area was sampled at the two study sites in California. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site.

Table 4. Canopy and ground cover (%) for study sites in California.

Cover category	**Site L1**	**Site L2**
Grass	43.3	74.4
Forb	53.0	3.0
Shrub	0.0	0.0
Cactus	0.0	0.0
Half-Shrub	0.0	0.0
Standing Dead	0.0	0.0
Total canopy cover	**96.3**	**77.3**
Basal vegetation	11.6	1.7
Cryptogam <1cm	0.7	0.0
Cryptogam >1cm	0.0	1.8
Litter	37.4	90.1
Rock	0.0	0.1
Bare soil	50.3	6.2
Total ground cover	**49.7**	**93.8**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for the California sites. Value of 0.0 denotes absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site L1	Site L2
Native grasses and sedges		
California oatgrass (*Danthonia californica* Boland.)	0.0	4.0
purple needlegrass (*Stipa pulchra* A.S. Hitchc.)	0.0	18.0
Total of native grasses and sedges	**0.0**	**22.0**
Native forbs and other herbaceous plants		
dwarf plantain (*Plantago erecta* Morris)	34.5	5.3
thistle (*Cirsium* P. Mill.)	18.5	0.0
common pussypaws (*Cistanthe monandra* (Nutt.) Hershkovitz)	15.5	0.0
plantain (*Plantago* L.)	2.6	0.0
common lomatium (*Lomatium utriculatum* (Nutt. ex Torr. & Gray) Coult. & Rose)	1.5	0.0
trefoil (*Lotus* L.)	0.5	0.0
geranium (*Geranium* L.)	0.0	Tr
Total of native forbs and other herbaceous plants	**73.1**	**5.3**
Introduced grasses		
ryegrass (*Lolium* L.)	1038.3	454.0
purple falsebrome (*Brachypodium distachyon* (L.) Beauv.)	89.1	228.8
soft brome (*Bromus hordeaceus* ssp. *hordeaceus* L.)	40.5	9.6
slender oat (*Avena barbata* Pott ex Link)	3.0	58.5
leporinum barley (*Hordeum murinum* ssp. *leporinum* (Link) Arcang.)	0.0	3.8
Total of introduced grasses	**1171.0**	**754.8**
Introduced forbs and other herbaceous plants		
cretanweed (*Hedypnois cretica* (L.) Dum.-Cours.)	1162.6	0.0
burclover (*Medicago polymorpha* L.)	128.0	16.3
spiny sowthistle (*Sonchus asper* (L.) Hill)	73.6	9.5
narrowleaf plantain (*Plantago lanceolata* L.)	12.0	0.0
scarlet pimpernel (*Anagallis arvensis* L.)	Tr	0.0
stork's bill (*Erodium* L'Her. ex Ait.)	Tr	0.0
Total of introduced forbs and other herbaceous plants	**1376.3**	**25.8**
Total average live plant annual yield	2620.5	817.0
Soil surface residue and standing dead plant material		
non-woody litter	177.3	1730.0
manure	0.0	152.0
Total of soil surface residue and standing dead plant material	**177.3**	**1882.0**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in California.

Sample depth	Site L1	Site L2
0-1"	880.1	957.5
1-4"	502.4	732.5
0-4" (total)	1382.5	1690.0

Hydrology

All 12 plot-runs conducted in California were suitable for inclusion in analyses. One plot-run had total runoff greater than applied rainfall. This situation is incorrect, but the plot-run has not been excluded from the current analysis. Equilibrium infiltration rates could not be determined for any of the dry plot-runs.

Table 7. Hydrology results for study sites in California. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site L1	Site L2
Dry plot-runs at antecedent soil moisture		
Total rainfall (mm)	56.78	61.93
Uniform rainfall rate (mm h^{-1})	56.78	57.17
Rainfall duration (minutes)	60.00	65.00
Total runoff (mm)	0.08	1.55
Runoff to rainfall ratio (mm mm^{-1})	0.00	0.02
Time to start of runoff (minutes)	54.10	41.22
Peak runoff rate (mm h^{-1})	0.69	7.34
Time to peak runoff (minutes)	40.00	26.50
Initial abstraction depth (mm)	53.17	41.03
Recession depth (mm)	0.02	0.37
Total sediment yield (kg ha^{-1})	0.28	6.73
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	1.10	1.46
Equilibrium infiltration rate (mm h^{-1})	-.- _	-.-
Wet plot-runs 24 h after dry plot-runs were not conducted in California		
Very wet plot-runs 30 minutes after wet plot-runs		
Total rainfall (mm)	99.75	109.97
Rainfall duration (minutes)	85.33	98.67
Total runoff (mm)	64.48	79.06
Runoff to rainfall ratio (mm mm^{-1})	0.66	0.72
Time to start of runoff (minutes)	15.06	19.58
Peak runoff rate (mm h^{-1})	88.70	98.57
Time to peak runoff (minutes)	59.83	64.33
Initial abstraction depth (mm)	15.34	18.60
Recession depth (mm)	2.11	3.15
Total sediment yield (kg ha^{-1})	412.63	332.12
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	6.40	4.24

_ value could not be determined

NRST Rangeland Sites in Colorado

Site Descriptions

Three short grass prairie sites, **F1, F2,** and **F3,** were sampled in Colorado during September 1991. Study sites **F1** (NW ¼ of SW ¼ of S24 T5N R52W, 40° 22′ 56″ N, 103° 7′ 42″ W) and **F2** (SE ¼ of SE ¼ of S24 T5N R52W, 40° 22′ 56″ N, 103° 8′ 17″ W) were located approximately 15 miles NNE of Akron, CO, in Washington County. Study site **F3** (SE ¼ of NE ¼ of S10 T10N R55W, 40° 51′ 29″ N, 103° 29′ 54″ W) was located approximately 32 miles NW of Sterling, CO, in Logan County. The following descriptions apply to all three study sites unless otherwise noted. The Soil Conservation District (SCD) for study sites **F1** and **F2** is Rock Creek, and the local NRCS office is the Akron Field Office. The SCD for study site **F3** is Centennial, and the local NRCS office is the Sterling Field Office. The Major Land Resource Area is the Central High Plains (MLRA No. 67) of the Western Great Plains Range and Irrigated Region. About three-fifths of this MLRA is in range of short and mid grasses grazed by cattle and sheep (USDA, SCS, 1981).

The range cover type is Blue grama-Buffalograss of the Northern Great Plains region. This is the true short grass range cover type of the northern and central plains (Barker and Whitman, 1994a). It primarily occurs on upland sites. The dominant shortgrasses are blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths) and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.). Midgrasses almost universally present include western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), and red threeawn (*Aristida purpurea* var. *robusta*) (Weaver and Albertson, 1956). Forbs are common, especially plains pricklypear. Woody plants are not regularly an important component of the vegetation (Barker and Whitman, 1994a).

The range site is **Loamy Plains**. The historic climax plant community would be composed of 80-90% grasses, with 5-10% forbs and 2-10% shrubs. Blue grama, western wheatgrass, and green needlegrass (*Stipa viridula* Trin.) would be the dominant grasses in the potential natural vegetation. Needleandthread (*Stipa comata* Trin. & Rupr.), buffalo grass, sun sedge (*Carex inops* ssp. *heliophila* (Mackenzie) Crins), and fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.) would be secondary species (USDA, SCS, 1983). The potential average annual production during normal years is 1200 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 900 pounds per acre or less and, in favorable years, annual productions can reach 1600 pounds per acre (USDA, SCS, 1986, and 1973b).

Study sites **F1**, **F2**, and **F3** were selected because they represented three contrasting vegetation states that are relevant to the Blue Grama-Buffalograss range cover type. All of the study sites were dominated by grasses. Study sites **F1** and **F2** were both dominated by blue grama. However, western wheatgrass was a strong component of the vegetation on site **F1** but only occurred in trace amounts on site **F2**. Study site **F1** also appeared to be more productive and have more litter (mulch) on the soil surface than did study site **F2**. Buffalograss occurred on all three sites but only in small amounts on study sites **F1** and **F2**. On study site **F3,** blue grama and buffalograss were nearly equal in their domination of the site, with a lesser amount of pricklypear cacti. The productivity of study site **F3** was much lower than that of study sites **F1** and **F2** and the litter (mulch) also was significantly less.

Climate

The climate at these sites is semiarid and continental. The average annual precipitation at the Central Great Plains Research Station, Akron, CO, is 16.43 inches. The average annual snowfall is 32.7 inches. The average daily temperature is 48.5 °F. In 5 years in 10, the last freezing temperature (32 °F) occurs on or after May 11. The first freezing temperature occurs on or after September 28. The minimum growing season in 9 out of 10 years is 123 days. The average annual precipitation at Sterling, CO, is 15.10 inches. The average annual snowfall is 30.4 inches. The average daily temperature is 48.6 °F. The minimum growing season in 9 out of 10 years is 121 days (USDA, SCS, 1986).

Soils

The soils at these sites are Stoneham loams. This soil is classified as fine-loamy, mixed, mesic Aridic Haplustalfs. In Washington County, the study sites were mapped as Stoneham loam, 6 to 9 percent slopes. These soils formed in gently rolling areas on plains and are derived from eolian sediment eroded from the Ogallala formation (USDA, SCS, 1986). In Logan County, the study site was mapped Stoneham loam, 5 to 9 percent slopes. These soils occur on upland ridges and hills and were derived from calcareous, loamy eolian and alluvial parent materials (USDA, SCS, 1973b). The NSSL pedon numbers for the representative pedons at each site are 92P0185, 92P0190, and 92P0180 for sites **F1**, **F2**, and **F3**, respectively. Tables 1a, 1b, 1c, 2a, 2b, and 2c present some selected soil chemical and physical properties for study sites **F1**, **F2**, and **F3**.

Bulk density was sampled on six plots at each study site, using either the compliant cavity or the balloon ecavation methods. Bulk density was measured at three positions and two depths before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **F1**, **F2**, and **F3**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **F1** were **57.6%** and **4.5%,** respectively. The respective values at study site **F2** were **59.7%** and **6.4%** and for study site **F3** were **53.0%** and **9.5%**.

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 92P0185 at study site **F1** in Colorado.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-2	L	49.9	33.3	16.8	1.00	Tr 1/
Bt1	2-13	SCL	52.7	23.7	23.6	1.44	2
Bt2	13-25	SCL	51.2	20.9	27.9	1.44	2
Btk1	25-41	CL	39.1	26.6	34.3	1.42	3
Btk2	41-66	C	25.3	26.8	47.9	1.45	3
2Bk3	66-91	C	12.8	30.4	56.8	1.45	5
2Bk4	91-107	C	13.2	35.6	51.2	1.33	1
BCk	107-124	SIC	14.7	42.7	42.6	1.17	4
Ck	124-152	CL	25.0	42.7	32.3	1.17	6

1/ Tr = Trace Amount

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 92P0190 at study site **F2** in Colorado.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-8	FSL	55.9	30.8	13.3	1.34	Tr
Bt1	8-23	SL	69.1	12.8	18.1	1.54	12
Bt2	23-43	SL	73.2	10.5	16.3	1.68	21
Btk1	43-64	SCL	62.5	14.9	22.6	1.61	7
Btk2	64-86	SCL	60.3	16.1	23.6	1.49	11
BCk	86-114	SCL	61.7	16.5	21.8	1.47	8
2Bk1	114-127	SCL	45.9	27.8	26.3	1.51	5
2Bk2	127-152	CL	44.5	20.3	35.2	1.50	2

Table 1c. Some selected soil properties of National Soil Survey Laboratory pedon number 92P0180 at study site **F3** in Colorado.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-8	FSL	61.9	20.1	18.0	1.34	2
Bt1	8-25	SCL	54.4	16.2	29.4	1.48	14
Bt2	25-37	SCL	57.5	18.0	24.5	1.46	24
2Btk	37-60	SCL	46.5	25.8	27.7	1.45	3
2Bk1	60-81	CL	43.4	27.8	28.8	1.38	5
2Bk2	81-115	CL	23.8	42.0	34.2	1.39	5
2BCk	115-139	CL	26.2	42.7	31.1	1.39	22
Cr	139-152	CL	31.2	40.4	28.4	-.-- 2/	25

2/ measure not taken on sample

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 92P0185 at study site **F1** in Colorado.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-2	2.72	-	0.13	15.0	6.8
Bt1	2-13	0.94	-	0.16	19.2	7.0
Bt2	13-25	0.90	-	0.10	23.6	8.0
Btk1	25-41	0.77	-	0.18	23.8	8.4
Btk2	41-66	0.72	-	0.20	30.9	8.6
2Bk3	66-91	0.55	-	0.18	41.4	5.8
2Bk4	91-107	0.36	-	0.19	41.2	8.7
BCk	107-124	0.23	-	0.19	42.5	8.7
Ck	124-152	0.13	-	0.11	43.2	8.7

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 92P0190 at study site **F2** in Colorado.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-8	1.75	-	0.14	12.4	7.0
Bt1	8-23	0.87	-	0.10	16.0	7.0
Bt2	23-43	0.53	-	0.04	12.6	8.0
Btk1	43-64	0.35	-	0.09	15.3	8.4
Btk2	64-86	0.27	-	0.13	16.3	8.5
BCk	86-114	0.24	-	0.12	16.0	8.6
2Bk1	114-127	0.26	-	0.12	20.1	8.6
2Bk2	127-152	0.16	-	0.16	27.0	8.5

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2c. Additional selected soil properties of National Soil Survey Laboratory pedon number 92P0180 at study site **F3** in Colorado.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-8	1.59	-	0.07	14.9	6.8
Bt1	8-25	0.99	-	0.07	21.9	7.6
Bt2	25-37	0.71	-	0.10	19.3	8.2
2Btk	37-60	0.37	-	0.11	20.7	8.6
2Bk1	60-81	0.30	-	0.15	20.7	8.8
2Bk2	81-115	0.31	-	0.15	24.3	8.6
2BCk	115-139	0.30	-	0.12	23.2	8.5
Cr	139-152	0.28	-	Tr	21.6	8.3

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in Colorado.

Sample time and depth	**Site F1**	**Site F2**	**Site F3**
before dry run, 0-1"	0.54	0.96	0.83
before dry run, 1-4"	1.28	1.46	1.35
before dry run, 0-4" (weighted average)	1.10	1.34	1.22
after very wet run, 0-1"	0.70	0.96	0.66
after very wet run, 1-4"	1.19	1.46	1.32
after very wet run, 0-4" (weighted average	1.07	1.34	1.16

Management History

It is assumed that past management has created vegetation and soil surface condition differences between the three sites. Study sites **F1** and **F2** occur in the same 468-acre field. This field was created by fencing a 2900-acre field in 1984. Prior to 1984, the field was continuously grazed by cattle for over 100 years. Since fencing in 1984, a short duration rest-rotation grazing system has been in use. The actual use prior to clipping for biomass estimates in 1991 was 500 animal unit months, with short duration grazing periods in the spring, summer, and fall. This field is also grazed by bulls, horses, and antelope. No range treatments have been applied and there is no record of the sites having been burned.

Study site **F3** is in a 68 acre field. This area has been continuously grazed for over a 100 years. The actual use prior to clipping for biomass estimates in 1991 was 7 animal unit months with spring, summer, and fall grazing.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. The study site plot-average is presented in Table 4. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Their plot-average values are presented in Table 5. Annual production of pricklypear (*Opuntia* P. Mill.) was assumed to be 10% of standing live biomass.

Below ground root biomass also was measured for all plots at each study site. A relatively uniformly spaced plant community with no interspaces was present at the sites; therefore, only a single type of representative area was sampled at the three study sites in Colorado. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site.

Table 4. Canopy and ground cover (%) for study sites in Colorado.

Cover category	Site F1	Site F2	Site F3
Grass	49.8	42.0	27.2
Forb	0.7	0.2	0.2
Shrub	0.0	0.0	0.0
Cactus	0.1	0.1	0.4
Half-Shrub	0.0	0.0	0.0
Standing Dead	3.2	1.9	0.0
Total canopy cover	**53.8**	**44.3**	**27.8**
Basal vegetation	18.3	22.0	7.1
Cryptogam <1cm	0.3	6.2	6.2
Cryptogam >1cm	0.0	0.0	0.0
Litter	76.9	57.3	68.7
Rock	0.0	0.0	0.1
Bare soil	4.4	14.5	17.9
Total ground cover	**95.6**	**85.5**	**82.1**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Colorado sites. Value of 0.0 denotes absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site F1	Site F2	Site F3
Native grasses and sedges			
blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)	706.3	789.1	187.6
western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love)	396.1	0.1	0.0
buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.)	13.1	8.7	222.4
sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray)	7.2	1.0	0.0
sun sedge (*Carex inops* ssp. *heliophila* (Mackenzie) Crins)	0.7	12.3	0.0
sixweeks fescue (*Vulpia octoflora* (Walt.) Rydb.)	0.0	Tr	0.0
Fendler threeawn (*Aristida purpurea* var. *longiseta* (Steud.) Vasey)	0.0	7.1	0.9
bottlebrush squirreltail (*Elymus elymoides* (Raf.) Swezey)	0.0	11.5	0.0
Total of native grasses and sedges	**1123.5**	**830.2**	**410.9**
Native forbs and other herbaceous plants			
rush skeletonplant (*Lygodesmia juncea* (Pursh) D. Don ex Hook.)	2.3	0.0	Tr
American vetch (*Vicia americana* Muhl. ex Willd.)	<0.1	0.0	0.0
ambrosia (*Ambrosia cumanensis* Kunth)	0.0	Tr	0.0
wild mint (*Mentha arvensis* L.)	0.0	0.2	0.0
crazyweed (*Oxytropis* DC.)	0.0	0.0	Tr
slimflower scurfpea (*Psoralidium tenuiflorum* (Pursh) Rydb.)	0.0	0.1	0.0
woolly plantain (*Plantago patagonica* Jacq.)	Tr	Tr	0.0
scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb.)	Tr	<0.1	0.1
Total of native forbs and other herbaceous plants	**2.4**	**0.4**	**0.1**
Native shrubs and cacti			
pricklypear (*Opuntia* P. Mill.)	0.0	Tr	15.4
Total of native shrubs and cacti	**0.0**	**Tr**	**15.4**
Introduced forbs and other herbaceous plants			
mustard (*Brassica* L.)	0.0	Tr	0.0
bull thistle (*Cirsium vulgare* (Savi) Ten.)	0.0	Tr	0.0
other annual forb	Tr	Tr	0.0
other perennial forb	Tr	Tr	0.0
Total of introduced forbs and other herbaceous plants	**0.0**	**Tr**	**0.0**
Total average live plant annual yield	**1125.9**	**830.6**	**426.5**
Soil surface residue and standing dead plant material			
non-woody litter	2130.3	1753.0	1788.6
Total of soil surface residue and standing dead plant material	**2130.3**	**1753.0**	**1788.6**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Colorado.

Sample depth	Site F1	Site F2	Site F3
0-1"	4381.3	10683.0	8622.1
1-4"	4034.4	4008.0	10955.2
0-4" (total)	8415.7	14691.0	19577.3

Hydrology

All 54 plot-runs in Colorado were considered suitable to be included in analyses. Table 7 presents a summary of some pertinent hydrologic results.

Table 7. Hydrology Results for study sites in Colorado. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site F1	Site F2	Site F3
Dry plot-runs at antecedent soil moisture			
Total rainfall (mm)	59.14	58.00	55.71
Uniform rainfall rate (mm h^{-1})	59.14	58.00	55.71
Rainfall duration (minutes)	60.00	60.00	60.00
Total runoff (mm)	16.77	19.43	19.89
Runoff to rainfall ratio (mm mm^{-1})	0.28	0.33	0.36
Time to start of runoff (minutes)	7.30	5.92	4.46
Peak runoff rate (mm h^{-1})	27.80	28.60	28.40
Time to peak runoff (minutes)	52.00	51.83	21.33
Initial abstraction depth (mm)	7.59	6.04	4.34
Recession depth (mm)	1.32	1.11	0.64
Total sediment yield (kg ha^{-1})	121.72	119.94	488.53
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	8.29	6.56	27.25
Equilibrium infiltration rate (mm h^{-1})	32.96	30.51	35.86
Wet plot-runs 24 h after dry plot-runs			
Total rainfall (mm)	38.47	32.67	34.13
Uniform rainfall rate (mm h^{-1})	58.71	56.38	56.15
Rainfall duration (minutes)	39.33	34.67	36.67
Total runoff (mm)	19.25	9.48	15.64
Runoff to rainfall ratio (mm mm^{-1})	0.49	0.29	0.47
Time to start of runoff (minutes)	8.19	5.33	3.55
Peak runoff rate (mm h^{-1})	47.53	29.08	39.67
Time to peak runoff (minutes)	26.67	24.33	21.33
Initial abstraction depth (mm)	8.52	5.48	3.51
Recession depth (mm)	2.63	0.95	1.78
Total sediment yield (kg ha^{-1})	81.90	88.81	195.76
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	5.18	9.74	12.85
Equilibrium infiltration rate (mm h^{-1})	14.75	32.78	20.84

Table 7 continued

Very wet plot-runs 30 minutes after wet plot-runs			
Total rainfall (mm)	75.93	69.38	77.68
Rainfall duration (minutes)	62.00	60.67	67.17
Total runoff (mm)	51.79	37.54	49.82
Runoff to rainfall ratio (mm mm^{-1})	0.68	0.55	0.65
Time to start of runoff (minutes)	4.56	3.37	3.14
Peak runoff rate (mm h^{-1})	94.42	78.42	87.95
Time to peak runoff (minutes)	35.67	36.50	36.33
Initial abstraction depth (mm)	4.78	3.19	3.28
Recession depth (mm)	2.17	1.01	1.56
Total sediment yield (kg ha^{-1})	251.83	284.06	448.09
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	5.09	7.79	9.02

NRST Rangeland Sites in Idaho

Site Descriptions

Two shrub-steppe sites, **J1** and **J2**, were sampled in Bingham County, Idaho, during August, 1992. Study sites **J1** (NW ¼ of SW ¼ of S21 T4S R40E, 43° 3′ 6″ N, 111° 46′ 40″ W) and **J2** (SE ¼ of NE ¼ of S7 T4S R40E, 43° 5′ 21″ N, 111° 48′ 15″ W) were approximately 27 miles SE of Blackfoot, ID. Both sites were located on privately owned grazing lands. The following descriptions apply to both sites unless indicated otherwise. The relevant Soil and Water Conservation District is North Bingham, and the relevant NRCS office is the Blackfoot Field Office. The Major Land Resource Area (MLRA No. 13) is Eastern Idaho Plateau of the Northwestern Wheat and Range Region. About one-half of this MLRA is used for range (USDA, SCS, 1981). Bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Love) and big sagebrush (*Artemisia tridentata* Nutt.) are the dominant species in the native grass-shrub vegetation of this MLRA (USDA, SCS, 1981).

The range cover type is Mountain Big Sagebrush of the Great Basin Region (Shiflet, 1994). The vegetation consists of the dominant shrub mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* (Rydb.) Beetle), with a well developed understory of perennial grasses and forbs. The principal grasses are Idaho fescue (*Festuca idahoensis* Elmer) and bluebunch wheatgrass. Sandberg bluegrass (*Poa secunda* J. Presl), mountain brome (*Bromus marginatus* Nees ex Steud.), slender wheatgrass (Elymus caninus (L.) L.[= bearded wheatgrass]), prairie junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schultes), oniongrass (*Melica* L.), western needlegrass (*Stipa occidentalis* var. *occidentalis* Thurb. ex S. Wats.), and sedges (*Carex* L.) also may occur in significant amounts. This range cover type is the most mesic of the big sagebrush cover types, occurring at relatively higher elevations than the other types. This type usually occurs as the upper elevation sagebrush zone just below the taller shrub or forest communities (Tisdale, 1994). The Mountain Big Sagebrush cover type responds to heavy grazing by a decrease in palatable grasses and forbs and an increase in sagebrush cover and vigor. Cheatgrass (*Bromus tectorum* L.) increases but to a lesser extent than in the drier sagebrush cover types (Tisdale, 1994). Mountain big sagebrush is easily killed by fire but establishes readily from seed to form dense stands (Tisdale, 1994).

The range site is **Loamy**, precipitation zone 16-22 inches (Loamy PZ 16-22). This range site occurs on nearly level to gently sloping mountain slopes and plateaus at elevations between 5000-6000 feet. Soils are moderately deep to very deep, with loamy to gravelly loamy textures. Composition by weight of the potential natural vegetation is 70-80% grasses, 10-20% forbs, and 5-15% shrubs. The potential average annual production during normal years is 1900 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 1200 pounds per acre or less and, in favorable years, annual productions can reach 2400 pounds per acre (USDA, SCS, 1980a).

Study sites **J1** and **J2** were selected because they represent two contrasting vegetation states that are relevant to the Mountain Big Sagebrush range cover type. Study site **J1** was dominated by mountain big sagebrush and had a significant shrub canopy on the site. Study site **J2** was dominated by grasses, mainly Letterman needlegrass and Sandberg bluegrass, with no significant shrub canopy, due to chemical control of the brush eight years before sampling. The amount of bare soil and mulch (litter) was similar on both sites.

Climate

The location is over 1000 feet higher than the closest climate station in Blackfoot, ID. The elevation change reduces the relevance of the best available climate summaries. Generally, Robin soils occur in areas that receive an average annual precipitation of 17-19 inches , have a mean annual air temperature of 36-40 °F, and have a frost-free period of between 50 and 80 days (USDA, SCS, 1973a).

Soils

Soils at both sites are in the Robin series. Robin soils are classified as fine-silty, mixed, Cryic Pachic Paleborolls. Soils at study site **J1** are mapped as Robin-Gilispie complex, rolling (mapping symbol RPF) (Robin silt loam). Robin soils occur on ridgetops and slopes, and the Gilispie soils occur on breaks and in the bottom of drainageways (USDA, SCS, 1973a). Soils at study site **J2** are mapped as Robin silt loam, 4 to 12 percent slopes (mapping symbol RoD). This unit occurs in high mountain valleys (USDA, SCS, 1973a). The mapping unit at study site **J1** formed in moderately weathered loess from mixed sources over moderately weathered alluvium from igneous rocks. At study site **J2,** the mapping unit formed in moderately weathered loess from mixed sources. The NSSL pedon numbers for the representative soil pedon at each site are 93P0048 and 93P0053 for study sites **J1** and **J2**, respectively. Tables 1a, 1b, 2a, and 2b present some selected soil chemical and physical properties for study sites **J1** and **J2**. Bulk density was sampled on six plots at each study site, using the balloon excavation method. Bulk density was measured at three positions and two depths 4 times before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **J1** and **J2**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **J1** were **46.8%** and **21.6%**, respectively. The respective values at study site **J2** were **67.2%** and **7.8%**.

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 93P0048 at study site **J1** in Idaho.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-7	SIL	16.3	66.3	17.4	-.-- 1/	Tr 2/
A2	7-27	SIL	13.3	67.5	19.2	1.23	Tr
AB	27-50	SIL	14.4	67.1	18.5	1.42	Tr
Bw	50-78	SIL	15.5	66.5	18.0	1.49	Tr
Bt1	78-118	SIL	14.6	62.0	23.4	1.64	3
Bt2	118-166	SIL	15.5	62.7	21.8	-.--	3
2Btk	166-200	CL	31.6	38.5	29.9	-.--	54

1/ measure not taken on sample

2/ Tr = Trace Amount

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 93P0053 at study site **J2** in Idaho.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-6	SIL	14.8	67.8	17.4	-.--	-
A2	6-32	SIL	13.5	67.4	19.1	1.17	-
AB	32-60	SIL	11.5	69.3	19.2	1.21	-
Bt1	60-107	SIL	13.5	66.6	19.9	1.49	-
Bt2	107-140	SIL	14.1	67.1	18.8	1.43	-
BC	140-199	SIL	14.3	65.8	19.9	1.43	-
C	199-250	-	--.-	--.-	--.-	-.--	-

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 93P0048 at study site **J1** in Idaho.

Horizon	Horizon depths (cm)	Organic carbon [1/] (%)	Total [2/] Nitrogen (%)	Water retention difference [3/] (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-7	5.60	0.44	Tr	27.6	5.5
A2	7-27	2.97	0.25	0.14	24.8	6.5
AB	27-50	1.95	0.15	0.12	20.7	6.8
Bw	50-78	0.95	0.07	0.15	16.0	7.1
Bt1	78-118	0.31	0.02	0.14	17.9	7.3
Bt2	118-166	0.16	0.01	Tr	20.1	7.0
2Btk	166-200	0.18	0.01	Tr	25.6	8.0

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 93P0053 at study site **J2** in Idaho.

Horizon	Horizon depths (cm)	Organic carbon [1/] (%)	Total [2/] Nitrogen (%)	Water retention difference [3/] (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-6	8.06	0.64	Tr	34.5	5.3
A2	6-32	3.98	0.32	0.13	27.7	6.0
AB	32-60	2.44	0.18	0.19	23.0	6.5
Bt1	60-107	0.64	0.05	0.15	16.7	6.8
Bt2	107-140	0.40	0.01	0.16	17.0	7.0
BC	140-199	0.28	0.01	0.16	17.6	7.0
C	199-250	0.24	-.--	Tr	16.8	8.2

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in Idaho.

Sample time and depth	**Site J1**	**Site J2**
before dry run, 0-1"	0.73	0.66
before dry run, 1-4"	1.02	1.02
before dry run, 0-4" (weighted average)	0.95	0.93
after very wet run, 0-1"	0.68	0.48
after very wet run, 1-4"	0.87	0.93
after very wet run, 0-4" (weighted average	0.82	0.81

Management History

Study site **J1** is grazed by sheep and cattle. In a typical year both sheep and cattle are turned out May 20; sheep are off July 1; back on September 1; and Cattle are out September 10. There is no grazing system, and the current level of use was not described. The study site has not received any mechanical range treatments or seedings but was chemically treated to control brush over 15 years before sampling. The effectiveness of this treatment is unknown. The study site is rarely if ever burned.

Study site **J2** is in a 160-acre field. It is grazed by cattle for two weeks only in the spring and is rested the remainder of the year. The study site has not received any mechanical range treatments or seedings but was chemically sprayed in June, 1984, to control brush (95% control, 2 pounds active ingredient, butyl ester 2- 4D). The study site is rarely if ever burned.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values. Annual production of mountain big sagebrush, threetip sagebrush (*Artemisia tripartita* Rydb.), green rabittbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.), Oregongrape (*Mahonia repens* (Lindl.) G. Don), and Woods' rose (*Rosa woodsii* Lindl.) was assumed to be 30% of standing live biomass of leaves and non-woody stems. Live woody stem total biomass was recorded separately.

Below ground root biomass also was measured for all plots at each study site. Areas in plant interspaces and under plant canopies were sampled separately at study site **J1.** At study site **J2**, a relatively uniformly spaced plant community with no interspaces was present, therefore; only a single type of surface area was sampled. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site and surface type.

Table 4. Canopy and ground cover (%) for study sites in Idaho.

Cover category	**Site J1**	**Site J2**
Grass	29.7	78.6
Forb	0.9	4.1
Shrub	38.0	3.3
Cactus	0.0	0.0
Half-Shrub	0.0	0.0
Standing Dead	2.2	0.7
Total canopy cover	**70.9**	**86.7**
Basal vegetation	5.3	8.2
Cryptogam <1cm	0.1	0.0
Cryptogam >1cm	0.0	0.0
Litter	84.6	84.4
Rock	0.0	0.0
Bare soil	10.1	7.4
Total ground cover	**89.9**	**92.6**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Idaho sites. Value of 0.0 denotes an absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site J1	Site J2
Native grasses and sedges		
Letterman Needlegrass (*Stipa lettermanii* Vasey)	188.6	573.6
Sandberg bluegrass (*Poa secunda* J. Presl)	87.6	448.8
prairie Junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schultes)	12.6	101.0
western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love)	5.0	58.1
sedge (*Carex* L.)	1.5	12.1
threadleaf sedge (*Carex filifolia* Nutt.)	1.1	0.0
Idaho fescue (*Festuca idahoensis* Elmer)	0.1	0.0
Total of native grasses and sedges	**296.8**	**1193.8**
Native forbs and other herbaceous plants		
eriogonum (*Eriogonum* Michx.)	30.3	48.3
aster (*Aster* L.)	4.0	1.0
common yarrow (*Achillea millefolium* L.)	0.8	3.5
pussytoes (*Antennaria* Gaertn.)	0.0	0.5
sticky geranium (*Geranium viscosissimum* Fisch. & C.A. Mey. ex C.A. Mey.)	0.0	60.8
common dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers)	0.0	Tr
goatsbeard (*Tragopogon* L.)	0.0	Tr
knotweed (*Polygonum* L.)	Tr	1.1
Total of native forbs and other herbaceous plants	**35.1**	**115.3**
Native shrubs and cacti		
mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* (Rydb.) Beetle)	264.5	0.0
green rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.)	5.6	39.0
threetip sagebrush (*Artemisia tripartita* Rydb.)	4.6	0.0
Oregongrape (*Mahonia repens* (Lindl.) G. Don)	0.3	0.0
Woods' rose (*Rosa woodsii* Lindl.)	0.0	72.6
Total of native shrubs and cacti	**275.1**	**111.6**
Introduced forbs and other herbaceous plants		
mustard (*Brassica* L.)	0.1	0.0
toadflax (*Linaria* P. Mill.)	0.0	0.8
Total of introduced forbs and other herbaceous plants	**0.1**	**0.8**
Total average live plant annual yield	**607.3**	**1421.6**

Table 5 continued

Soil surface residue and standing dead plant material		
standing-live wood	8075.3	16.8
non-woody litter	6413.3	4428.3
woody litter	1137.5	86.0
manure	205.0	967.5
standing-dead wood	166.6	0.0
standing-dead grass	0.0	2.0
Total of soil surface residue and standing dead plant material	**15997.8**	**5500.6**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Idaho.

	Under Plant Canopy [1/]		Plant Interspace[2/]	
Sample depth	**Site J1**	**Site J2**	**Site J1**	**Site J2**
0-1"	5004.0	10461.9	3492.2	-
1-4"	2314.3	5278.1	1753.8	-
0-4" (total)	7318.3	15740.0	5246.0	-

1/ Samples taken in area under plant canopies.
2/ Samples taken in open areas not under plant canopies.

Hydrology

All 36 plot-runs in Idaho were considered suitable to be included in analyses. Table 7 presents a summary of some pertinent hydrologic results.

Table 7. Hydrology Results for study sites in Idaho. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site J1	Site J2
Dry plot-runs at antecedent soil moisture		
Total rainfall (mm)	54.58	54.94
Uniform rainfall rate (mm h^{-1})	54.58	54.94
Rainfall duration (minutes)	60.00	60.00
Total runoff (mm)	4.56	6.24
Runoff to rainfall ratio (mm mm^{-1})	0.08	0.11
Time to start of runoff (minutes)	9.08	5.89
Peak runoff rate (mm h^{-1})	7.50	8.90
Time to peak runoff (minutes)	37.00	34.33
Initial abstraction depth (mm)	8.60	5.81
Recession depth (mm)	0.19	0.30
Total sediment yield (kg ha^{-1})	28.79	17.99
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	6.01	3.52
Equilibrium infiltration rate (mm h^{-1})	49.30	47.42

Table 7 continued

Wet plot-runs 24 h after dry plot-runs		
Total rainfall (mm)	45.19	36.00
Uniform rainfall rate (mm h^{-1})	55.85	57.90
Rainfall duration (minutes)	48.67	37.33
Total runoff (mm)	4.63	2.63
Runoff to rainfall ratio (mm mm^{-1})	0.11	0.07
Time to start of runoff (minutes)	16.22	11.26
Peak runoff rate (mm h^{-1})	12.72	9.72
Time to peak runoff (minutes)	43.67	32.17
Initial abstraction depth (mm)	15.65	11.36
Recession depth (mm)	0.56	0.23
Total sediment yield (kg ha^{-1})	38.84	8.85
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	7.12	4.01
Equilibrium infiltration rate (mm h^{-1})	44.32	50.66

Very wet plot-runs 30 minutes after wet plot-runs		
Total rainfall (mm)	93.30	86.56
Rainfall duration (minutes)	79.33	72.00
Total runoff (mm)	25.62	20.10
Runoff to rainfall ratio (mm mm^{-1})	0.29	0.23
Time to start of runoff (minutes)	6.64	7.24
Peak runoff rate (mm h^{-1})	58.78	50.46
Time to peak runoff (minutes)	47.17	39.00
Initial abstraction depth (mm)	6.61	7.33
Recession depth (mm)	0.50	0.22
Total sediment yield (kg ha^{-1})	185.58	72.21
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	6.65	4.09

NRST Rangeland Sites in Kansas

Site Descriptions

Three tall grass prairie sites, **E1, E2,** and **E3,** were sampled in Greenwood County, Kansas, during August, 1991. Study site **E1** (SE ¼ of SE ¼ of S34 T27S R11E, 37° 38′ 32″ N, 96° 10′ 48″ W) was located approximately 12 miles SE of Eureka, KS and miles NE of Severy, KS. Study site **E2** (SW ¼ of SE ¼ of S22 T25S R9E, 37° 51′ 53″ N, 96° 23′ 47″ W) was located approximately 6 miles WNW of Eureka, KS and 5 miles NNE of Reece, KS. Study site **E3** (SE ¼ of SE ¼ of S24 T25S R8E, 37° 51′ 27″ N, 96° 27′ 58″ W) was located approximately 5 miles NW of Reece, KS, and 9 miles WNW of Eureka, KS. All three study sites were located on privately owned land.

The following descriptions apply to all three study sites unless otherwise noted. The Major Land Resource Area (MLRA No. 76) is the Bluestem Hills in the Central Great Plains Winter Wheat and Range Region. Three-fifths of this MLRA is in native grasses grazed by cattle. The dominant grasses of the native tall grass prairie are big bluestem (*Andropogon gerardii* Vitman), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), Indiangrass (*Sorghastrum nutans* (L.) Nash), and switchgrass (*Panicum virgatum* L.) (USDA, SCS, 1981).

The range cover type is Bluestem Prairie in the Northern Great Plains Region. This tall grass prairie range cover type, now largely eliminated by cultivation east of the plains border, is dominated by warm-season grasses (Barker and Whitman, 1994b). Dominant grass species are big bluestem, switchgrass, Indiangrass, and little bluestem (Barker and Whitman, 1994b).

The range site is **Loamy Upland**. The potential average annual production during normal years is 5000 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 4000 pounds per acre or less and, in favorable years, annual productions can reach 6000 pounds per acre (USDA, SCS, 1982a).

Study sites **E1**, **E2**, and **E3** were selected because they represent three very different vegetation states relevant to the southern portion of the Bluestem Prairie range cover type. Study site **E1** appeared to be dominated by annual weedy plants such as annual broomweed, (*Amphiachyris dracunculoides* (DC.) Nutt.), annual ragweed (*Ambrosia artemisiifolia* L.), smooth crabgrass (*Digitaria ischaemum* (Schreb.) Muhl.), and other low seral stage plants, although a few tall grass prairie species such as big bluestem, Indiangrass, and eastern gramagrass (*Tripsacum dactyloides* (L.) L.) were still present in the form of small weak plants. Study site **E2** represented a very productive vegetation state in a high seral stage for the tall grass prairie and was dominated by grasses such as big bluestem, Indiangrass, and little bluestem. Study site **E3** represented a less productive vegetation state dominated by short and mid height grasses, buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), and little bluestem, respectively, with very few weedy plants on the site. Study site **E3** also appeared to have less surface mulch and more bare soil than the other two Kansas study sites.

Climate

The climate of Greenwood County, Kansas, is typically continental, with cold winters, warm summer temperatures for about 6 months, and short spring and fall periods (USDA, SCS, 1982d). Large diurnal variations in air temperature are characteristic (USDA, SCS, 1982d). The mean annual precipitation at Eureka, KS, is 37.65 inches. The average annual snowfall is 18.1 inches. The mean daily temperature is 56.8 °F. In 5 years in 10, the last freezing temperature (32 °F) occurs on or after April 14. The first freezing temperature occurs on or after October 21. The minimum growing season in 9 out of 10 years is 169 days (USDA, SCS, 1982d).

Soils

The soils at these sites were correlated with the Martin series. The soils at these sites are referred to as "Martin like" and are very similar to and are included in the Martin map units because use and management are the same as for Martin. The representative soil pedons sampled at site **E1, E2** and **E3** were classified as a fine, semectitic, mesic Typic Hapluderts. The NSSL pedon numbers for the representative pedons at each site are 91P0846, 91P0836, and 91P0841 for sites **E1**, **E2**, and **E3**, respectively. Tables 1a, 1b, 1c, 2a, 2b, and 2c present some selected soil chemical and physical properties for study sites **E1**, **E2**, and **E3**.

Bulk density was sampled on six plots at each study site, using either the compliant cavity or the balloon excavation methods. Bulk density was measured at three positions and two depths before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **E1**, **E2**, and **E3**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **E1** were **86.0%** and **1.9%,** respectively. The respective values at study site **E2** were **60.8%** and **45.0%** and for study site E3 were **56.8%** and **36.9%.**

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 91P0846 at study site **E1** in Kansas.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-21	SIC	4.8	50.9	44.3	1.60	-
BA	21-36	SIC	5.5	47.8	46.7	1.87	Tr 2/
Bt	36-59	SIC	5.2	46.9	47.9	1.74	-
Bss1	59-97	SIC	7.5	43.8	48.7	1.82	15
Bss2	97-137	SIC	6.1	44.3	49.6	1.79	10
C	137-160	SIC	7.5	48.3	44.2	-.-- 1/	6

1/ measure not taken on sample

2/ Tr = Trace Amount

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 91P0836 at study site **E2** in Kansas.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-20	SIC	11.1	48.3	40.6	1.35	-
A2	20-33	SIC	9.2	45.8	45.0	1.63	-
BA	33-45	SIC	7.1	40.8	52.1	1.73	-
Bt1	45-58	SIC	8.3	41.1	50.6	1.75	Tr
Bt2	58-77	SIC	6.7	40.4	52.9	1.87	Tr
Bss1	77-101	C	6.7	38.9	54.4	1.89	Tr
Bssk	101-122	C	8.4	36.8	54.8	1.85	3
Bss	122-140	C	11.8	36.2	52.0	1.83	7
C1	140-154	C	23.2	35.7	41.1	-.--	8
C2	154-180	SICL	18.4	48.2	33.4	-.--	-

Table 1c. Some selected soil properties of National Soil Survey Laboratory pedon number 91P0841 at study site **E3** in Kansas.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry ($g\ cm^{-3}$)	Coarse fragments (% by weight)
A1	0-10	SIC	2.7	53.9	43.4	1.42	-
A2	10-28	SIC	2.4	48.1	49.5	1.67	-
Bt	28-47	SIC	3.5	42.6	53.9	1.76	-
Bss1	47-77	SIC	1.8	42.1	56.1	1.93	2
Bss2	77-119	SIC	4.1	40.4	55.5	1.95	3
Bss3	119-137	SIC	4.8	43.0	52.2	1.89	Tr
C	137-147	SIC	3.3	48.3	48.4	-.--	3
Cr	147-200	SIC	7.9	51.6	40.5	1.85	-

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 91P0846 at study site **E1** in Kansas.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-21	4.23	0.37	0.16	53.6	6.7
BA	21-36	2.17	0.19	0.16	39.2	7.0
Bt	36-59	1.40	0.13	0.14	47.9	7.5
Bss1	59-97	0.57	-.--	0.12	42.0	7.9
Bss2	97-137	0.33	-.--	0.14	30.7	7.8
C	137-160	0.24	-.--	Tr	28.3	7.9

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 91P0836 at study site **E2** in Kansas.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-20	4.36	0.34	0.04	45.5	6.3
A2	20-33	2.65	0.23	0.03	44.5	6.4
BA	33-45	1.81	0.18	0.10	34.3	6.6
Bt1	45-58	1.29	0.13	0.11	45.4	6.6
Bt2	58-77	0.90	-.--	0.10	34.0	6.7
Bss1	77-101	0.48	-.--	0.08	33.3	7.6
Bssk	101-122	0.31	-.--	0.09	43.0	8.0
Bss	122-140	0.33	-.--	0.11	40.9	8.1
C1	140-154	0.41	-.--	Tr	36.5	8.1
C2	154-180	0.14	-.--	Tr	29.9	8.1

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2c. Additional selected soil properties of National Soil Survey Laboratory pedon number 91P0841 at study site **E3** in Kansas.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-10	4.34	0.23	Tr	44.4	6.5
A2	10-28	2.65	0.23	Tr	45.7	6.5
Bt	28-47	1.65	0.15	0.13	45.5	7.0
Bss1	47-77	0.98	-.--	0.10	44.7	7.8
Bss2	77-119	0.38	-.--	0.18	37.8	8.1
Bss3	119-137	0.22	-.--	0.08	28.3	8.1
C	137-147	0.12	-.--	Tr	22.6	8.2
Cr	147-200	0.10	-.--	0.08	18.4	8.2

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in Kansas.

Sample time and depth	**Site E1**	**Site E2**	**Site E3**
before dry run, 0-1"	0.89	0.74	0.79
before dry run, 1-4"	1.17	1.13	1.09
before dry run, 0-4" (weighted average)	1.10	1.04	1.01
after very wet run, 0-1"	0.76	1.09	0.95
after very wet run, 1-4"	1.04	1.13	1.02
after very wet run, 0-4" (weighted average)	0.97	1.12	1.01

Management History

Study site **E1** is rangeland; it is grazed yearlong by cattle, is rarely if ever burned, and had some mechanical brush management (small trees and shrubs cutoff) within the last year (year before sampling date). Study site **E2** also is rangeland, is not currently grazed although it is normally slightly grazed during the summer; is occasionally burned, but had not been burned in several years and has had no brush management. Study site **E3** is rangeland and has heavy use by cattle from May to October; it is occasionally burned and had been burned on March 22, 1991, by a wildfire. Whether or not brush management has occurred at study site **E3** is unknown.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values. Below ground root biomass also was measured for all plots at each study site. A relatively uniformly spaced plant community with no interspaces was present at the sites; therefore, only a single type of representative area was sampled at the three study sites in Kansas. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site.

Table 4. Canopy and ground cover (%) for study sites in Kansas.

Cover category	Site E1	Site E2	Site E3
Grass	21.8	52.2	32.2
Forb	32.7	6.7	5.0
Shrub	0.2	0.0	0.0
Cactus	0.0	0.0	0.0
Half-Shrub	0.0	0.0	0.0
Standing Dead	1.0	2.0	0.9
Total canopy cover	**55.6**	**60.9**	**38.2**
Basal vegetation	2.0	2.1	3.0
Cryptogam <1cm	0.0	0.0	0.0
Cryptogam >1cm	0.0	0.0	0.0
Litter	70.5	74.3	55.2
Rock	0.0	0.0	0.0
Bare soil	27.4	23.6	41.8
Total ground cover	**72.6**	**76.4**	**58.2**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Kansas sites. Value of 0.0 denotes an absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site E1	Site E2	Site E3
Native grasses and sedges			
tall dropseed (*Sporobolus asper* (Beauv.) Kunth)	160.7	70.9	11.3
smooth crabgrass (*Digitaria ischaemum* (Schreb.) Muhl.)	115.5	0.0	0.0
sedge (*Carex* L.)	35.6	6.1	Tr
fescue (*Festuca* L.)	28.6	0.0	0.0
Kentucky bluegrass (*Poa pratensis* L.)	21.4	21.4	0.0
eastern gramagrass (*Tripsacum dactyloides* (L.) L.)	16.3	9.3	0.0
witchgrass (*Panicum capillare* L.)	11.7	0.2	5.4
big bluestem (*Andropogon gerardii* Vitman)	5.1	654.2	29.6
yellow Indiangrass (*Sorghastrum nutans* (L.) Nash)	0.8	424.0	4.9
bristlegrass (*Setaria* Beauv.)	0.2	0.0	0.0
hairy grama (*Bouteloua hirsuta* Lag.)	<0.1	0.0	0.0
buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.)	<0.1	0.0	139.0
tumble windmill grass (*Chloris verticillata* Nutt.)	<0.1	0.0	0.0
fall panicgrass (*Panicum dichotomiflorum* Michx.)	0.0	0.0	Tr
windmill grass (*Chloris* Sw.)	0.0	0.0	Tr
Scribner's rosette grass (*Dichanthelium oligosanthes* var. *scribnerianum* (Nash) Gould)	0.0	4.9	Tr
fall panicum (*Dichanthelium wilcoxianum* (Vasey) Freckmann)	0.0	2.3	0.0
switchgrass (*Panicum virgatum* L.)	0.0	55.0	Tr
little bluestem (*Schizachyrium scoparium* (Michx.) Nash)	0.0	666.9	96.9
sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)	Tr	11.7	121.4
blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)	Tr	0.0	0.0
rush (*Juncus* L.)	Tr	0.0	0.0
Total of native grasses and sedges	**396.5**	**1927.2**	**408.9**

Table 5 continued

Native forbs and other herbaceous plants			
prairie broomweed (*Amphiachyris dracunculoides* (DC.) Nutt.)	609.7	0.0	0.0
Missouri goldenrod (*Solidago missouriensis* Nutt.)	245.6	18.9	46.8
ambrosia (*Ambrosia cumanensis* Kunth)	89.7	2.8	5.2
stiff goldenrod (*Solidago rigida* L.)	76.1	4.7	0.0
annual ragweed (*Ambrosia artemisiifolia* L.)	74.4	34.1	0.0
snow on the mountain (*Euphorbia marginata* Pursh)	42.6	0.0	0.0
prairie fleabane (*Erigeron strigosus* Muhl. ex Willd.)	32.6	0.0	0.0
Baldwin's ironweed (*Vernonia baldwinii* Torr.)	30.1	0.0	0.0
heath aster (*Aster ericoides* L.)	23.2	29.8	25.9
Maximilian sunflower (*Helianthus maximiliani* Schrad.)	19.9	0.0	0.0
spotted sandmat (*Chamaesyce maculata* (L.) Small)	18.4	Tr	0.0
lanceleaf fogfruit (*Phyla lanceolata* (Michx.) Greene)	10.9	0.0	0.0
povertyweed (*Iva axillaris* Pursh)	7.0	0.0	0.0
lespedeza (*Lespedeza* Michx.)	6.5	0.0	0.0
wild mint (*Mentha arvensis* L.)	5.7	0.0	0.0
Canadian horseweed (*Conyza canadensis* (L.) Cronq.)	5.0	0.0	0.0
selfheal (*Prunella* L.)	4.8	0.0	0.0
fringeleaf wild petunia (*Ruellia humilis* Nutt.)	3.3	8.8	Tr
Texas croton (*Croton texensis* (Klotzsch) Muell.-Arg.)	2.4	0.0	Tr
common dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers)	2.1	0.0	0.0
hoary verbena (*Verbena stricta* Vent.)	0.4	0.0	0.0
great ragweed (*Ambrosia trifida* L.)	0.0	0.0	Tr
common sunflower (*Helianthus annuus* L.)	0.0	<0.1	0.0
field pussytoes (*Antennaria neglecta* Greene)	0.0	Tr	0.0
Louisiana sagewort (*Artemisia ludoviciana* Nutt.)	0.0	Tr	0.0
whorled milkweed (*Asclepias verticillata* L.)	0.0	Tr	0.0
purple prairieclover (*Dalea purpurea* Vent.)	0.0	0.0	3.5
eastern purple coneflower (*Echinacea purpurea* (L.) Moench)	0.0	0.0	Tr
fuzzybean (*Strophostyles* Ell.)	Tr	0.0	0.0
common yarrow (*Achillea millefolium* L.)	Tr	Tr	Tr
common yellow oxalis (*Oxalis stricta* L.)	Tr	Tr	0.0
Canada goldenrod (*Solidago canadensis* L.)	Tr	0.0	0.0
Total of native forbs and other herbaceous plants	**1311.0**	**99.5**	**81.5**
Native shrubs and cacti			
leadplant (*Amorpha canescens* Pursh)	0.0	16.6	11.3
catclaw (*Mimosa nuttallii* (DC.) B.L. Turner)	0.0	19.0	0.0
mariola (*Parthenium incanum* Kunth)	0.0	0.0	4.0
azure blue sage (*Salvia azurea* Michx. ex Lam.)	0.0	6.8	0.0
Total of native shrubs and cacti	**0.0**	**42.5**	**15.4**

Table 5 continued

Introduced grasses			
broomcorn millet (*Panicum miliaceum* L.)	0.2	0.0	0.0
other perennial grass	0.0	Tr	0.0
Total of introduced grasses	**0.2**	**0.0**	**0.0**
Introduced forbs and other herbaceous plants			
giant sumpweed (*Iva xanthifolia* Nutt.)	19.0	0.0	0.0
bull thistle (*Cirsium vulgare* (Savi) Ten.)	4.4	0.0	0.0
mustard (*Brassica* L.)	0.9	0.0	0.0
other annual forb	0.0	0.0	Tr
other perennial forb	0.0	0.0	1.6
flower of an hour (*Hibiscus trionum* L.)	Tr	0.0	0.0
field clover (*Trifolium campestre* Schreb.)	Tr	0.0	0.0
Total of introduced forbs and other herbaceous plants	**24.4**	**0.0**	**1.6**
Total average live plant annual yield	**1732.4**	**2069.3**	**507.5**
Soil surface residue and standing dead plant material			
non-woody litter	1678.7	1310.0	386.8
Total of soil surface residue and standing dead plantmaterial	**1678.7**	**1310.0**	**386.8**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Kansas.

Sample depth	Site E1	Site E2	Site E3
0-1"	3696.6	9981.8	5014.9
1-4"	1831.9	6904.0	6247.0
0-4" (total)	5528.5	16885.8	11261.9

Hydrology

Not all of the 54 plot-runs in Kansas are suitable for use in analyses. The 12 dry plot-runs at study sites **E1** and **E2** each had less than 1 mm of total runoff. This small volume of runoff is insufficient to accurately portray the hydrological response of these plots under the stated conditions. At best they may be used to indicate a lower limit of hydrologic response. In addition, at study site **E2** a mechanical breakdown of the rainfall simulator caused an additional 1-day delay (2 days total) between the dry and wet plot-runs for plots 1 and 2. Because of the vertic nature of these soils, the additional time, which allowed swelling of the soils, must be considered as a factor in interpreting differences between study sites and plot-runs within a study site. The dry plot-runs at site **E3** were suitable for inclusion in analysis. The wet plot-runs at site **E1** also were too low and should be considered unsuitable for some analyses. At site **E2**, two of the wet runs produced runoff, but these plot-runs were of considerably longer duration than the four plot-runs that did not produce runoff. Care should be taken when these plot-runs are used in analyses. Table 7 presents a summary of some pertinent hydrologic results. The results in this table are based on averages across all 6 plots, if not missing. As stated above, several plot-runs may be considered unsuitable.

Table 7. Hydrology Results for study sites in Kansas. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site E1	Site E2	Site E3
Dry plot-runs at antecedent soil moisture			
Total rainfall (mm)	57.54	58.08	57.53
Uniform rainfall rate (mm h^{-1})	54.99	58.08	57.53
Rainfall duration (minutes)	63.33	60.00	60.00
Total runoff (mm)	0.17	0.02	2.17
Runoff to rainfall ratio (mm mm^{-1})	0.00	0.00	0.04
Time to start of runoff (minutes)	14.19	2.43	26.41
Peak runoff rate (mm h^{-1})	0.52	0.08	5.59
Time to peak runoff (minutes)	28.33	3.33	49.00
Initial abstraction depth (mm)	13.15	2.67	17.22
Recession depth (mm)	0.01	-.--_	0.14
Total sediment yield (kg ha^{-1})	1.45	0.28	17.65
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	12.06	2.81	7.39
Equilibrium infiltration rate (mm h^{-1})	57.67	-.--	51.14
Wet plot-runs 24 h after dry plot-runs			
Total rainfall (mm)	49.68	79.94	26.28
Uniform rainfall rate (mm h^{-1})	55.83	54.52	59.42
Rainfall duration (minutes)	53.33	87.00	26.67
Total runoff (mm)	1.73	9.13	9.98
Runoff to rainfall ratio (mm mm^{-1})	0.02	0.07	0.39
Time to start of runoff (minutes)	13.75	29.33	4.91
Peak runoff rate (mm h^{-1})	5.26	13.75	31.84
Time to peak runoff (minutes)	46.00	43.33	13.67
Initial abstraction depth (mm)	10.79	-.--	5.44
Recession depth (mm)	0.19	0.62	1.16
Total sediment yield (kg ha^{-1})	17.22	112.14	92.71
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	10.62	4.20	8.92
Equilibrium infiltration rate (mm h^{-1})	55.28	15.58	28.97

Table 7 continued

Very wet plot-runs 30 minutes after wet plot-runs			
Total rainfall (mm)	95.19	74.02	77.28
Rainfall duration (minutes)	74.67	64.67	58.67
Total runoff (mm)	52.29	41.95	51.32
Runoff to rainfall ratio (mm mm^{-1})	0.56	0.58	0.67
Time to start of runoff (minutes)	4.59	9.52	3.30
Peak runoff rate (mm h^{-1})	94.57	87.35	95.71
Time to peak runoff (minutes)	53.00	39.00	30.67
Initial abstraction depth (mm)	4.61	9.57	3.64
Recession depth (mm)	2.66	2.06	1.49
Total sediment yield (kg ha^{-1})	457.93	358.76	537.65
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	8.64	8.68	10.54

– value not calculated or derived

NRST rangeland sites in Nebraska

Site Descriptions

Two tall grass prairie study sites, **B1 and B2,** were sampled in Saunders County, Nebraska, during June, 1990. Study sites **B1** (NW ¼ of SW ¼ of S29 T13N R5E, 41° 3′ 58″ N, 96° 53′ 18″ W) and **B2** (SW ¼ of NW ¼ of S32 T13N R5E, 41° 3′ 14″ N, 96° 52′ 37″ W) were approximately 3 miles WSW of Valparaiso, NE and approximately 15 miles SW of Wahoo, NE. The two study sites were approximately 1 mile from each other. The following description applies to both study sites unless otherwise noted. The relevant NRCS offices are the Wahoo field office and the Lincoln area office. The Major Land Resource Area (MLRA No. 106) is the Nebraska and Kansas Loess-drift hills of the Central Feed Grains and Livestock Region. About one quarter of this MLRA is in pasture or native range; typically pastures of native grasses are on strongly sloping to steep soils that formed in glacial till and pastures of introduced grasses and legumes are on better soils (USDA, SCS, 1981).

The range cover type is Bluestem Prairie in the Northern Great Plains Region. This tall grass prairie range cover type, now largely eliminated by cultivation east of the plains border, is dominated by warm-season grasses (Barker and Whitman, 1994b). Dominant grass species are big bluestem (*Andropogon gerardii* Vitman), switchgrass (*Panicum virgatum* L.), Indiangrass (*Sorghastrum nutans* (L.) Nash), and little bluestem (*Schizachyrium scoparium* (Michx.) Nash) (Barker and Whitman, 1994b).

The range site is **Silty**. The potential average annual production during normal years is 3250 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 2750 pounds per acre or less and, in favorable years, annual productions can reach 3250 pounds per acre (USDA, SCS, 1980b).

Study sites **B1** and **B2** were selected because they represented two common but very contrasting vegetation states that are relevant in the northern portion of the Bluestem Prairie range cover type. Study site **B2** represents a typical high seral vegetation state dominated by tall grasses such as big bluestem (*Andropogon gerardii* Vitman), Indiangrass (*Sorghastrum nutans* (L.), and porcupine grass (*Hesperostipa spartea* (Trin.) Barkworth) in association with many high seral stage forbs. Study site **B1** represents a low seral vegetation state dominated by Kentucky bluegrass (*Poa pratensis* L.), a cool season sod forming grass. Under grazing, the short grass component of the Bluestem Prairie becomes apparent. Although not a true short grass, Kentucky bluegrass under heavy grazing may form a short, dense sod (Weaver and Tomanek, 1951).

Climate

At Lincoln, NE, the average annual precipitation is 29.9 inches, 70% of which usually occurs between April and September (USDA, SCS, 1980b). In winter, the average temperature is 27 °F and average seasonal snowfall is 28 inches. July is the hottest month, with average daily temperatures of 76.6 °F. Burchard series soils occur in regions with average annual air temperature between 51-56 °F, 160-180 frost free days, and 25-33 inches of average annual precipitation.

Soils

Soils at both sites in Nebraska are classified in the Burchard series. They are Burchard clay loams. The Burchard series is classified as a fine-loamy, mixed, mesic Typic Argiudolls. The Burchard series consists of soils that are well drained, have a clay loam or clay surface layer and subsoil, a very deep root zone, moderately slow permeability, and formed in limy glacial till on uplands (USDA, SCS, 1965). The NSSL pedon numbers for the representative soil pedon at each site are 90P0688 and 90P0693 for study sites **B1** and **B2**, respectively. Tables 1a, 1b, 2a, and 2b present some selected soil chemical and physical properties for study sites **B1** and **B2**.

Bulk density was sampled on six plots at each study site, using the compliant cavity excavation method. Bulk density was measured at three positions and two depths before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **B1** and **B2**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **B1** were **67.2%** and **6.8%,** respectively. The respective values at study site **B2** were **81.2%** and **3.3%.**

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 90P0688 at study site **B1** in Nebraska.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-3	CL	28.1	41.0	30.9	-.- 1/	Tr 2/
A2	3-5	CL	26.2	42.6	31.2	-.-	3
A3	5-18	CL	27.1	36.3	36.6	1.56	2
AB	18-31	CL	28.8	31.8	39.4	1.76	2
Bt	31-49	CL	30.1	31.1	38.8	1.81	2
Btk1	49-72	CL	29.2	37.9	32.9	1.78	2
Btk2	72-92	CL	30.1	37.3	32.6	1.71	4
Btk3	92-110	CL	29.4	38.6	32.0	1.83	9
BC	110-140	CL	31.1	37.0	31.9	1.90	2
C	140-160	CL	32.8	33.6	33.6	1.73	3

1/ measure not taken on sample

2/ Tr = Trace Amount

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 90P0693 at study site **B2** in Nebraska.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density Oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-5	CL	35.0	37.8	27.2	1.02	2
A2	5-16	CL	38.3	32.2	29.5	1.43	6
A3	16-28	CL	35.8	30.5	33.7	1.63	3
AB	28-40	CL	34.2	30.8	35.0	1.66	1
Bt	40-53	CL	32.7	35.2	32.1	1.68	4
Btk1	53-68	CL	32.3	37.0	30.7	1.75	5
Btk2	68-86	CL	30.5	39.6	29.9	1.80	6
Btk3	86-102	CL	31.2	38.5	30.3	1.88	3
BC	102-127	CL	31.5	37.7	30.8	1.86	3
C	127-152	CL	31.0	38.0	31.0	1.93	4

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 90P0688 at study site **B1** in Nebraska.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-3	10.09	0.87	-.-	41.4	6.1
A2	3-5	4.32	0.40	-.-	32.3	7.0
A3	5-18	2.32	0.21	0.15	31.0	7.1
AB	18-31	1.25	0.12	0.12	32.8	7.4
Bt	31-49	0.71	0.07	0.12	30.4	8.1
Btk1	49-72	0.32	-.-	0.11	23.0	8.2
Btk2	72-92	0.14	-.-	0.12	22.0	8.2
Btk3	92-110	0.06	-.-	0.09	20.9	8.1
BC	110-140	0.02	-.-	0.13	20.7	8.1
C	140-160	0.03	-.-	0.09	21.1	8.3

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 90P0693 at study site **B2** in Nebraska.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-5	4.57	0.40	0.16	29.0	7.2
A2	5-16	2.39	0.21	0.11	26.1	6.3
A3	16-28	1.80	0.16	0.14	26.3	7.2
AB	28-40	1.32	0.12	0.14	27.0	8.0
Bt	40-53	0.78	0.07	0.10	22.8	8.1
Btk1	53-68	0.54	-.-	0.09	19.7	8.2
Btk2	68-86	0.34	-.-	0.08	20.0	8.2
Btk3	86-102	0.19	-.-	0.10	18.9	7.9
BC	102-127	0.09	-.-	0.11	20.5	8.3
C	127-152	0.07	-.-	0.08	18.5	8.2

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in Nebraska.

Sample time and depth	**Site B1**	**Site B2**
before dry run, 0-1"	0.92	1.04
before dry run, 1-4"	1.56	1.24
before dry run, 0-4" (weighted average)	1.40	1.19
after very wet run, 0-1"	0.67	0.71
after very wet run, 1-4"	1.33	1.10
after very wet run, 0-4" (weighted average)	1.17	1.00

Management History

It assumed that past management has created vegetation and soil surface condition differences between the two study sites sampled in Nebraska.

Study site **B1** is in a 10 acre field that is described as currently and historically intensely grazed. It is currently used as a spring and summer pasture for calving. After calving it is used as a bull pasture. There is no indication that this site is ever rested. No brush management, mechanical treatment, burning, or fertilization has occurred on this site.

Study site **B2** is in a 20 acre pasture that is mowed for hay. This has also been its historic use. There is no indication that haying is ever deferred. Grazing has not occurred for at least 30 years. No brush management or mechanical treatment other than that incidental to mowing hay has occurred on this site. No burning or fertilization has occurred on this site.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values.

Below ground root biomass was also measured for all plots at each study site. A relatively uniformly spaced plant community with no interspaces was present at the sites; therefore, only a single type of representative area was sampled at the two study sites in Nebraska. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site.

Table 4. Canopy and ground cover (%) for study sites in Nebraska.

Cover category	**Site B1**	**Site B2**
Grass	9.4	10.2
Forb	17.9	7.2
Shrub	0.0	5.2
Cactus	0.0	0.0
Half-Shrub	0.0	0.0
Standing Dead	0.0	0.1
Total canopy cover	**27.2**	**22.7**
Basal vegetation	6.7	2.4
Cryptogam <1cm	0.0	0.0
Cryptogam >1cm	0.0	0.0
Litter	72.9	86.0
Rock	0.0	0.0
Bare soil	20.4	11.6
Total ground cover	**79.6**	**88.4**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Nebraska sites. Value of 0.0 denotes an absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site B1	Site B2
Native grasses and sedges		
Kentucky bluegrass (*Poa pratensis* L.)	691.1	82.5
foxtail barley (*Hordeum jubatum* L.)	9.5	0.0
smooth brome (*Bromus inermis* Leyss.)	6.1	277.4
fall panicgrass (*Panicum dichotomiflorum* Michx.)	4.0	0.0
big bluestem (*Andropogon gerardii* Vitman)	3.3	377.8
sedge (*Carex* L.)	3.3	45.1
little barley (*Hordeum pusillum* Nutt.)	2.5	0.0
sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)	0.0	192.5
panicum (*Panicum* L.)	0.0	31.9
little bluestem (*Schizachyrium scoparium* (Michx.) Nash)	0.0	14.1
yellow Indiangrass (*Sorghastrum nutans* (L.) Nash)	0.0	344.4
dropseed (*Sporobolus asper* (Beauv.) Kunth)	0.0	59.2
porcupinegrass (*Hesperostipa spartea* (Trin.) Barkworth)	0.0	423.3
Total of native grasses and sedges	**719.9**	**1848.5**
Native forbs and other herbaceous plants		
common dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers)	117.3	0.0
annual ragweed (*Ambrosia artemisiifolia* L.)	54.9	0.0
Canadian horseweed (*Conyza canadensis* (L.) Cronq.)	41.8	96.7
slim amaranth (*Amaranthus hybridus* L.)	23.4	0.0
Virginia pepperweed (*Lepidium virginicum* L.)	11.3	0.0
lambsquarters (*Chenopodium* album L.)	0.8	0.0
field pussytoes (*Antennaria neglecta* Greene)	0.4	3.3
woolly plantain (*Plantago patagonica* Jacq.)	0.0	6.6
curlycup gumweed (*Grindelia squarrosa* (Pursh) Dunal)	0.0	25.0
common yarrow (*Achillea millefolium* L.)	0.0	25.8
heath aster (*Aster ericoides* L.)	0.0	189.4
woolly milkvetch (*Astragalus mollissimus* Torr.)	0.0	6.6
whorled milkweed (*Asclepias verticillata* L.)	0.0	0.1
purple prairieclover (*Dalea purpurea* Vent.)	0.0	3.3
common yellow oxalis (*Oxalis stricta* L.)	0.0	21.6
primrose (*Primula* L.)	0.0	546.6
slimflower scurfpea (*Psoralidium tenuiflorum* (Pursh) Rydb.)	0.0	155.1
stiff goldenrod (*Solidago rigida* L.)	0.0	5.0
vetch (*Vicia* L.)	0.0	7.5
Total of native forbs and other hervaceous plants	**250.3**	**1093.1**

Table 5 continued

Native shrubs and cacti		
leadplant (*Amorpha canescens* Pursh)	0.0	168.7
sand cherry (*Prunus pumila* L.)	0.0	38.3
Total of native shrubs and cacti	0.0	207.1
Introduced grasses		
green bristlegrass (*Setaria viridis* (L.) Beauv.)	4.3	9.1
Japanese brome (*Bromus japonicus* Thunb. ex Murr.)	0.7	41.8
yellow bristlegrass (*Setaria pumila* (Poir.) Roemer & J.A. Schultes)	<0.1	0.0
cheatgrass (*Bromus tectorum* L.)	0.0	116.2
Total of introduced grasses	5.2	167.1
Introduced forbs and other herbaceous plants		
alsike clover (*Trifolium hybridum* L.)	89.7	0.1
yellow sweetclover (*Melilotus officinalis* (L.) Lam.)	18.6	0.0
prostrate knotweed (*Polygonum aviculare* L.)	10.0	0.0
curly dock (*Rumex crispus* L.)	1.2	0.0
black medick (*Medicago lupulina* L.)	0.6	0.0
shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.)	<0.1	0.0
puncturevine (*Tribulus terrestris* L.)	<0.1	0.0
mustard (*Brassica* L.)	0.0	9.0
black bindweed (*Polygonum convolvulus* L.)	0.0	6.6
nodding plumeless thistle (*Carduus nutans* L.)	0.0	1.6
meadow salsify (*Tragopogon pratensis* L.)	0.0	107.5
field bindweed (*Convolvulus arvensis* L.)	0.0	0.8
other annual forb	0.0	0.8
Total of introduced forbs and other herbaceous plants	**120.4**	**126.7**
Total average live plant annual yield	**1099.9**	**3442.7**
Soil surface residue and standing dead plant material		
non-woody litter	574.5	762.5
Total of soil surface residue and standing dead plant material	**574.5**	**762.5**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Nebraska.

Sample depth	**Site B1**	**Site B2**
0-1"	10833.6	2278.8
1-4"	2101.5	1208.6
0-4" (total)	12935.1	3487.4

Hydrology

All 36 plot-runs in Nebraska were considered suitable for inclusion in most analyses. However, insufficient runoff was generated during the dry run at study site **B2**, only one plot had observable runoff, and hence equilibrium infiltration rate and runoff to rainfall ratio were not derived. The lack of observed runoff during these plot-runs at this study site makes interpretation of the other values more difficult.

Time to beginning of runoff, sediment yield, and sediment yield ratio are all averages of a single plot with 5 plots whose values are 0 or infinite. Comparisons based on differences between dry-runs should be made with due consideration of this situation. Runoff was observed on all subsequent wet and very wet plot-runs.

Table 7. Hydrology Results for sites in Nebraska. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site B1	Site B2
Dry plot-runs at antecedent soil moisture		
Total rainfall (mm)	53.99	51.39
Uniform rainfall rate (mm h^{-1})	53.99	50.36
Rainfall duration (minutes)	60.00	61.33
Total runoff (mm)	27.40	0.11 _
Runoff to rainfall ratio (mm mm^{-1})	0.51	-.-- _
Time to start of runoff (minutes)	11.14	18.67 _
Peak runoff rate (mm h^{-1})	35.78	0.63 _
Time to peak runoff (minutes)	36.67	10.00 _
Initial abstraction depth (mm)	4.14	14.79 _
Recession depth (mm)	2.07	0.02 _
Total sediment yield (kg ha^{-1})	234.88	1.27 _
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	8.82	1.90 _
Equilibrium infiltration rate (mm h^{-1})	19.93	-.-- _
Wet plot-runs 24 h after dry plot-runs		
Total rainfall (mm)	16.66	26.86
Uniform rainfall rate (mm h^{-1})	54.50	53.73
Rainfall duration (minutes)	18.33	30.00
Total runoff (mm)	8.29	1.80
Runoff to rainfall ratio (mm mm^{-1})	0.50	0.07
Time to start of runoff (minutes)	5.90	17.21
Peak runoff rate (mm h^{-1})	37.70	9.84
Time to peak runoff (minutes)	12.50	29.17
Initial abstraction depth (mm)	1.07	8.88
Recession depth (mm)	2.25	0.57
Total sediment yield (kg ha^{-1})	29.63	21.42
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	3.56	11.86
Equilibrium infiltration rate (mm h^{-1})	17.23	43.89

Table 7. Continued.

Description	Site B1	Site B2
Very wet plot-runs 30 minutes after wet plot-runs		
Total rainfall (mm)	40.17	47.83
Rainfall duration (minutes)	34.33	44.67
Total runoff (mm)	25.47	25.79
Runoff to rainfall ratio (mm mm^{-1})	0.63	0.54
Time to start of runoff (minutes)	3.49	7.29
Peak runoff rate (mm h^{-1})	67.17	71.87
Time to peak runoff (minutes)	18.83	26.83
Initial abstraction depth (mm)	1.86	1.97
Recession depth (mm)	2.67	1.66
Total sediment yield (kg ha^{-1})	72.52	192.97
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	2.83	7.37

– based upon averaging a single plot with observed values with 5 plots with 0 values

– value not calculated or derived

NRST Rangeland Sites in North Dakota

Site Descriptions

Three mixed-grass prairie sites, **H1**, **H2**, and **H3**, were sampled in Dunn County, North Dakota, during June, 1992. Study sites **H2** (NW ¼ of SE ¼ of S36 T146N R96W, 47° 25′ 30″ N, 102° 52′ 45″ W) and **H3** (NW ¼ of SE ¼ of S36 T146N R96W, 47° 25′ 30″ N, 102° 52′ 30″ W) were approximately 6 miles NW of Killdeer, ND. Study site **H1** (NW ¼ of SW ¼ of S36 T145N R97W, 47° 20′ N, 103° 0′ W) was approximately 11 miles SW of Killdeer, ND. The following descriptions apply to all three sites unless otherwise noted. The sites were located in the Dunn County Soil and Water Conservation District and local NRCS office was the Killdeer NRCS field office. All three study sites were on North Dakota State School Land. The Major Land Resource Area (MLRA No. 54) is the Rolling Soft Shale Plain of the Northern Great Plains Spring Wheat Region. About three-fifths of this MLRA remains in native grass and shrubs that are grazed (USDA, SCS, 1981). Dominant grasses in the native prairie areas of this MLRA are western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths), needleandthread grass (*Stipa comata* Trin. & Rupr.), and green needlegrass (*Nassella viridula* (Trin.) Barkworth) (USDA, SCS, 1981).

The range cover type is Prairie Sandreed - Needlegrass in the Northern Great Plains Region. Northward from Nebraska, the bluestems become less important, and prairie sandreed (*Calamovilfa longifolia* (Hook.) Scribn.) and needleandthread grass become the primary dominants, although sand bluestem (*Andropogon hallii* Hack.) and little bluestem (*Schizachyrium scoparium* (Michx.) Nash) are usually present. Big bluestem (*Andropogon gerardii* Vitman) is normally unimportant in this range cover type (Whitman and Barker, 1994b). Under intensive grazing, the short grass component, represented by blue grama and hairy grama (*Bouteloua hirsuta* Lag.), and upland sedges (*Carex* L.) increase (Whitman and Barker, 1994c).

The range site is **Sandy**. These sites occur on nearly level to rolling uplands and outwash plains with slopes from 0-15 percent. They also occur along river valleys on nearly level to strongly sloping terraces and fans. The historic climax plant community would be dominated by needleandthread grass, prairie sandreed, blue grama, and western wheatgrass. The potential average annual production during normal years is 2100 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 1700 pounds per acre or less and, in favorable years, annual productions can reach 2400 pounds per acre (USDA, SCS, 1982c).

Study sites **H1**, **H2**, and **H3** were selected from three contrasting vegetation states relevant to the Prairie Sandreed-Needlegrass Range Cover Type in the Northern Great Plains Region. The main reason for selecting these sites was to evaluate the impact of clubmoss (*Lycopodium* L.) on hydrology and erosion. Study site **H1** had very little clubmoss and was dominated by grasses typical for this soil type such as needleandthread grass, prairie sandreed, and sedges, with smaller amounts of blue grama, prairie junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schultes), and western wheatgrass. The productivity on study site **H1** was less than expected for the site. Study site **H2** was dominated by clubmoss and sedges, with the main grasses on the site being prairie junegrass and blue grama, in lesser amounts. Study site **H3** was dominated by sedges and blue grama, with lesser amounts of clubmoss. The percent of bare soil and mulch (litter) appeared to be very similar for all three study sites.

Climate

Dunn County is usually quite warm in the summer and very cold in the winter. Most precipitation falls during the warm period and is normally heaviest in the late spring and early summer (USDA, SCS, 1982c). There is an average annual precipitation of 17.26 inches at Killdeer, ND. Annual precipitation ranges from 9-24 inches. There is an average 35 inches of snowfall with 35-40 days with at least 6 inches of snow on the ground. The average frost free period (32° F) is from May 17 to September 27 (137 days). The freeze free period (28° F) is from May 12 to September 18, 122 days (Dean Chamrad, unpublished report).

Soils

Soils at all three sites are Parshall fine sandy loam, which is part of the Vebar-Parshall association. This map unit association occurs on nearly level to strongly sloping soils on uplands and terraces (USDA, SCS, 1982c). The Parshall series is classified as a coarse-loamy, mixed Pachic Haploboroll. Sampled pedons at all three sites were characteristic and within the range of the series. An Ap soil horizon was not present at any of the sites. The NSSL pedon numbers for the representative soil pedon at each study site are 92P0790, 92P0795, and 92P0800 for study sites **H1**, **H2**, and **H3**, respectively. Tables 1a, 1b, 1c, 2a, 2b and 2c present some selected soil properties for study sites in North Dakota. Bulk density was sampled on six plots at each study site, using either the compliant cavity or the balloon excavation methods. Bulk density was measured at three positions and two depths before and rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **H1**, **H2**, and **H3**. The average and standard deviation of aggregate stability (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **H1** were **83.8%** and **3.3%**, respectively. The respective values at study site **H2** were **85.3%** and **5.6%** and for study site **H3** were **74.0%** and **10.2%**.

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 92P0790 at study site **H1** in North Dakota.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry ($g\ cm^{-3}$)	Coarse fragments (% by weight)
A	0-3	FSL	53.1	30.7	16.2	-.-- 1/	3
AB	3-19	SL	67.4	17.9	14.7	1.57	Tr
Bw1	19-32	SL	71.6	13.4	15.0	1.54	1
Bw2	32-55	SL	69.2	14.6	16.2	1.54	2
Bw3	55-97	SL	70.9	14.2	14.9	1.57	2
Bk1	97-109	FSL	72.9	13.0	14.1	1.61	Tr
Bk2	109-165	SL	75.0	12.2	12.8	1.64	2
Bk3	165-195	SL	77.6	11.2	11.2	-.--	Tr
C1	195-275	SL	75.7	12.5	11.8	-.--	Tr
C2	275-342	FSL	78.3	12.1	9.6	-.--	Tr 2/

1/ measure not taken on sample
2/ Tr = Trace Amount

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 92P0795 at study site **H2** in North Dakota.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-3	FSL	56.3	27.6	16.1	-.--	2
AB	3-27	FSL	69.4	17.5	13.1	1.49	-
Bw1	27-48	FSL	74.4	13.0	12.6	1.51	-
Bw2	48-67	FSL	76.3	12.0	11.7	1.56	-
Bw3	67-85	FSL	76.5	12.6	10.9	-.--	-
Bw4	85-123	FSL	75.9	12.2	11.9	1.63	Tr
BC	123-150	LFS	80.6	11.3	8.1	1.56	-
C1	150-250	LFS	83.4	9.6	7.0	-.--	-
C2	250-300	LFS	80.2	12.0	7.8	-.--	1

Table 1c. Some selected soil properties of National Soil Survey Laboratory pedon number 92P0800 at study site **H3** in North Dakota.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-3	FSL	66.3	21.4	12.3	-.--	-
AB	3-19	FSL	73.3	16.2	10.5	1.51	Tr
Bw1	19-34	FSL	75.5	14.1	10.4	1.51	Tr
Bw2	34-64	FSL	77.9	13.0	9.1	1.55	-
Bw3	64-96	FSL	78.0	12.5	9.5	1.60	-
Bw4	96-205	FSL	77.8	12.1	10.1	1.61	Tr
2C	205-	FSL	62.6	21.3	16.1	-.--	1

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 92P0790 at study site **H1** in North Dakota.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-3	3.98	-	Tr	18.0	6.3
AB	3-19	1.74	-	0.08	12.8	6.4
Bw1	19-32	0.90	-	0.08	13.4	6.7
Bw2	32-55	0.72	-	0.11	14.6	7.0
Bw3	55-97	0.56	-	0.08	13.8	7.3
Bk1	97-109	0.40	-	0.08	12.8	8.0
Bk2	109-165	0.33	-	0.09	11.3	8.1
Bk3	165-195	0.26	-	Tr	10.5	8.2
C1	195-275	0.26	-	Tr	10.7	8.3
C2	275-342	0.14	-	Tr	8.3	8.4

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 92P0795 at study site **H2** in North Dakota.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-3	6.28	-	Tr	22.7	6.5
AB	3-27	1.80	-	0.14	14.5	6.3
Bw1	27-48	0.83	-	0.13	11.7	6.5
Bw2	48-67	0.53	-	0.08	11.3	6.7
Bw3	67-85	0.41	-	Tr	11.5	6.9
Bw4	85-123	0.33	-	0.10	12.5	7.1
BC	123-150	0.17	-	0.12	9.9	7.3
C1	150-250	0.11	-	Tr	8.7	7.4
C2	250-300	0.08	-	Tr	10.1	8.2

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC).

Table 2c. Additional selected soil properties of National Soil Survey Laboratory pedon number 92P0800 at study site **H3** in North Dakota.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-3	5.14	-	Tr	17.9	6.4
AB	3-19	1.62	-	0.12	11.8	6.2
Bw1	19-34	1.05	-	0.06	10.8	6.5
Bw2	34-64	0.67	-	0.12	9.1	6.6
Bw3	64-96	0.44	-	0.16	9.5	6.9
Bw4	96-205	0.27	-	0.09	10.4	7.0
2C	205-	0.20	-	Tr	15.0	7.3

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in North Dakota.

Sample time and depth	**Site H1**	**Site H2**	**Site H3**
before dry run, 0-1"	1.37	0.86	0.86
before dry run, 1-4"	1.21	1.09	1.31
before dry run, 0-4" (weighted average)	1.25	1.03	1.20
after very wet run, 0-1"	1.11	0.94	1.10
after very wet run, 1-4"	1.18	1.14	1.38
after very wet run, 0-4" (weighted average	1.16	1.09	1.31

Management History

All three sites are on rangeland in the same section that was fenced in 1925. The entire section was most likely hayed before cross-fencing into four, 160-acre pastures around 1958-1959. Available records indicate that the quarter section containing study sites **H2** and **H3** was hayed prior to 1925, was grazed between 1925 and 1930, and was hayed again between 1930 and 1958. This sequence probably also applies to the quarter section containing study site **H1**. There is no record of any fertilization, prescribed burning, or brush management (other than incidental to haying) ever having been performed at these study sites.

All three study sites have occasional use by antelope. Site **H1** was not grazed before sampling but would be grazed starting in July, 1992. The study site has recently had summer and fall season-long grazing in a 1 of 3-year rest cycle. The length of time for this management is unknown. The plant vigor was strong when the study site was sampled. Sites **H2** and **H3** are grazed by cattle from spring through fall. The length of time for this management is unknown. The plant vigor was weak when the study sites were sampled. Precipitation was below average from 1988-1990, was near average in 1991, and was again below average for the year during 1992.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. At all three study sites, clubmoss was recorded as cryptogam ground cover >1cm. Dead clubmoss was classified and recorded as litter. Occularly estimated clubmoss cover on the sub-plots sampled for plant biomass were a trace, **20.8**%, and **3.8**% for study sites **H1**, **H2**, and **H3**, respectively. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values.

Below ground root biomass was also measured for all plots at each study site. A relatively uniformly spaced plant community with no interspaces was present at the sites, therefore only a single type of representative area was sampled at the three study sites in North Dakota. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site.

Table 4. Canopy and ground cover (%) for study sites in North Dakota.

Cover category	Site H1	Site H2	Site H3
Grass	48.3	46.9	59.6
Forb	2.4	16.9	7.7
Shrub	0.5	0.4	0.1
Cactus	0.0	0.0	0.0
Half-Shrub	2.5	0.1	1.0
Standing Dead	28.2	4.9	2.3
Total canopy cover	**81.9**	**69.2**	**70.7**
Basal vegetation	3.4	10.4	13.2
Cryptogam <1cm	0.0	0.3	0.7
Cryptogam >1cm	1.1	21.4	5.1
Litter	92.0	64.1	69.4
Rock	0.0	0.0	0.0
Bare soil	3.5	3.8	11.6
Total ground cover	**96.5**	**96.2**	**88.4**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for North Dakota sites. Value of 0.0 denotes an absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site H1	Site H2	Site H3
Native grasses and sedges			
needleandthread grass (*Stipa comata* Trin. & Rupr.)	210.7	78.7	81.1
prairie sandreed (*Calamovilfa longifolia* (Hook.) Scribn.)	189.1	10.2	82.6
sedge (*Carex* L.)	157.1	331.5	365.4
prairie Junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schultes)	48.9	103.7	36.2
blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)	45.2	139.3	255.6
Kentucky bluegrass (*Poa pratensis* L.)	18.7	0.0	0.0
western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love)	17.1	8.9	3.5
Fendler threeawn (*Aristida purpurea* var. *longiseta* (Steud.) Vasey)	12.6	0.0	0.0
Scribner's rosette grass (*Dichanthelium oligosanthes* var. *scribnerianum* (Nash) Gould)	0.2	Tr	0.2
plains reedgrass (*Calamagrostis montanensis* Scribn. ex Vasey)	0.0	6.5	5.6
thickspick wheatgrass (*Elymus lanceolatus* ssp. *lanceolatus* (Scribn. & J.G. Sm.) Gould)	0.0	0.3	0.0
Sandberg bluegrass (*Poa secunda* J. Presl)	0.0	2.1	1.7
porcupinegrass (*Stipa spartea* Trin.)	0.0	10.2	0.0
Total of native grasses and sedges	**699.8**	**691.7**	**832.2**
Native forbs and other herbaceous plants			
Louisiana sagewort (*Artemisia ludoviciana* Nutt.)	24.9	18.1	99.0
rush skeletonplant (*Lygodesmia juncea* (Pursh) D. Don ex Hook.)	14.5	0.6	2.4
spiny phlox (*Phlox hoodii* Richards.)	11.1	23.9	12.5
blue lettuce (*Lactuca tatarica* var. *pulchella* (Pursh) Breitung)	9.0	0.0	0.0
blacksamson echinacea (*Echinacea angustifolia* DC.)	6.6	3.6	4.9
Lambert's crazyweed (*Oxytropis lambertii* Pursh)	2.0	Tr	1.1
fringed sagewort (*Artemisia frigida* Willd.)	1.4	1.1	43.4
silverleaf scurfpea (*Pediomelum argophyllum* (Pursh) J. Grimes)	0.7	0.0	0.2
pepperweed (*Lepidium* L.)	0.0	0.0	0.1
prairie trefoil (*Lotus unifoliolatus* var. *unifoliolatus* (Hook.) Benth.)	0.0	Tr	0.0
thistle (*Cirsium* P. Mill.)	0.0	Tr	0.0
western wallflower (*Erysimum asperum* (Nutt.) DC.)	0.0	0.4	0.0
anemone (*Anemone* L.)	0.0	239.3	0.0
pussytoes (*Antennaria* Gaertn.)	0.0	1.0	0.0
field sagewort (*Artemisia campestris* L.)	0.0	0.1	3.9
milkweed (*Asclepias* L.)	0.0	0.0	0.2
milkvetch (*Astragalus* L.)	0.0	0.6	0.0
hairy goldenaster (*Heterotheca villosa* (Pursh) Shinners)	0.0	14.3	0.0
dotted gayfeather (*Liatris punctata* Hook.)	0.0	5.2	2.7
sharppoint microseris (*Nothocalais cuspidata* (Pursh) Greene)	0.0	0.1	<0.1
cinquefoil (*Potentilla* L.)	0.0	0.4	0.0
sagebrush buttercup (*Ranunculus glaberrimus* Hook.)	0.0	0.8	0.0
prairie groundsel (*Senecio plattensis* Nutt.)	0.0	3.5	0.0
Missouri goldenrod (*Solidago missouriensis* Nutt.)	0.0	1.2	Tr

Table 5 continued

common dandelion (Taraxacum officinale G.H. Weber ex Wiggers)	0.0	0.0	1.0
prairie thermopsis (*Thermopsis rhombifolia* (Nutt. ex Pursh) Nutt. ex Richards.)	0.0	16.1	0.0
woolly plantain (*Plantago patagonica* Jacq.)	Tr	Tr	0.2
Total of native forbs and other herbaceous plants	**70.6**	**330.8**	**172.2**
Native shrubs and cacti			
common snowberry (*Symphoricarpos albus* (L.) Blake)	4.3	0.0	0.0
leadplant (*Amorpha canescens* Pursh)	0.0	0.0	0.1
rose (*Rosa* L.)	0.0	5.3	2.3
Total of native shrubs and cacti	**4.3**	**5.3**	**2.4**
Introduced grasses			
Canada bluegrass (*Poa compressa* L.)	0.5	0.0	0.0
Total of introduced grasses	**0.5**	**0.0**	**0.0**
Introduced forbs and other herbaceous plants			
mustard (*Brassica* L.)	0.7	27.7	1.5
prickly lettuce (*Lactuca serriola* L.)	0.0	0.0	0.9
field pennycress (*Thlaspi arvense* L.)	Tr	0.0	0.0
common chickweed (*Stellaria media* (L.) Vill.)	Tr	11.4	0.8
Total of introduced forbs and other herbaceous plants	**0.7**	**39.2**	**3.2**
Total average live plant annual yield	**776.0**	**1067.1**	**1010.2**
Soil surface residue and standing dead plant material			
non-woody litter	1533.9	655.4	1138.6
standing-dead grass	253.2	28.4	48.8
manure	252.0	258.2	774.5
club moss	**34.2**	**348.6**	**210.6**
Total of soil surface residue and standing dead plant material	**2073.5**	**1290.7**	**2172.6**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in North Dakota.

Sample depth	Site H1	Site H2	Site H3
0-1"	7347.7	16326.9	5537.0
1-4"	5600.3	3466.1	3021.3
0-4" (total)	12948.0	19793.0	8558.3

Hydrology

All 54 plot-runs in North Dakota were considered suitable to be included in analyses. However, at site **H1** it was concluded that runoff did not reach equilibrium, and therefore no equilibrium infiltration rate was determined. Runoff was observed on all plot-runs, but for all dry plot-runs at site **H2** and for 2 dry plot-runs at site **H1**, the amount of runoff (< 1 mm) may be considered as within the region of measurement error and should be considered as potentially 0 mm runoff. The inclusion of these plot-runs will depend on the specific analysis. Table 7 presents a summary of some pertinent hydrologic results.

Table 7. Hydrology Results for sites in North Dakota. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site H1	Site H2	Site H3
Dry plot-runs at antecedent soil moisture			
Total rainfall (mm)	53.58	54.86	54.81
Uniform rainfall rate (mm h^{-1})	53.58	54.86	54.81
Rainfall duration (minutes)	60.00	60.00	60.00
Total runoff (mm)	4.83	4.43	6.48
Runoff to rainfall ratio (mm mm^{-1})	0.09	0.08	0.12
Time to start of runoff (minutes)	5.19	8.74	4.32
Peak runoff rate (mm h^{-1})	17.82	9.65	11.33
Time to peak runoff (minutes)	10.50	24.83	27.00
Initial abstraction depth (mm)	5.19	8.49	4.43
Recession depth (mm)	0.00	0.07	0.14
Total sediment yield (kg ha^{-1})	24.11	73.06	47.47
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	6.92	17.43	6.93
Equilibrium infiltration rate (mm h^{-1})	-.--[†]	52.04	49.35
Wet plot-runs 24 h after dry plot-runs			
Total rainfall (mm)	51.78	38.17	33.08
Uniform rainfall rate (mm h^{-1})	58.50	57.30	58.38
Rainfall duration (minutes)	53.33	40.00	34.00
Total runoff (mm)	0.09	7.09	7.28
Runoff to rainfall ratio (mm mm^{-1})	0.00	0.18	0.22
Time to start of runoff (minutes)	15.07	13.46	10.73
Peak runoff rate (mm h^{-1})	0.39	23.47	26.07
Time to peak runoff (minutes)	31.33	34.50	30.33
Initial abstraction depth (mm)	15.09	13.56	11.02
Recession depth (mm)	0.00	0.68	1.07
Total sediment yield (kg ha^{-1})	0.63	85.31	67.84
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	5.43	10.19	8.55
Equilibrium infiltration rate (mm h^{-1})	-.--	35.63	33.75

Table 7 continued

Very wet plot-runs 30 minutes after wet plot-runs			
Total rainfall (mm)	98.77	64.60	64.84
Rainfall duration (minutes)	91.33	54.67	55.33
Total runoff (mm)	14.25	33.92	34.20
Runoff to rainfall ratio (mm mm^{-1})	0.14	0.53	0.53
Time to start of runoff (minutes)	14.54	6.68	4.89
Peak runoff rate (mm h^{-1})	34.96	85.43	82.28
Time to peak runoff (minutes)	49.83	30.50	33.67
Initial abstraction depth (mm)	13.91	6.58	4.74
Recession depth (mm)	0.02	0.99	1.30
Total sediment yield (kg ha^{-1})	61.68	430.08	245.81
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	4.36	12.44	6.97

† **value is unavailable or was not calculated**

NRST Rangeland Sites in Texas

Site Descriptions

Two short grass prairie sites, **C1** and **C2,** were sampled in Texas, during August, 1990. Study site C1 (35° 16′ 30″ N, 102° 16′ 46″ W) was located in Oldham County, approximately 5 miles NE of Vega, TX. Study site C2 (35° 16′ 30″ N, 102° 16′ 46″ W) was located in Randall County, approximately 5 miles SSE of Amarillo, TX. The two sites are separated by approximately 40 miles.

The following descriptions apply to both sites unless otherwise noted. The relevant NRCS offices are the Canyon (**C2**) and Vega (**C1**) Field Offices and the Amarillo Area Office. Sites **C1** and **C2** are in the Oldham and Randall Soil and Water Conservation District, respectively. The Major Land Resource Area is Southern High Plains, Southern Part (MLRA No. 77C) of the Central Great Plains Winter Wheat and Range Region. More than two-fifths of the Southern High Plains (all parts combined), consisting of breaks along the Cimarron and Canadian Rivers and their major tributaries and areas of sandy soils, is rangeland of native grasses and shrubs grazed by cattle (USDA, SCS, 1981).

The range cover type is Grama-Buffalograss of the Southern Great Plains Region. This short grass prairie range cover type is dominated by blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths) and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.), with blue grama usually most dominant (Bell, 1994). Woody vegetation is mostly absent in climax stands but, with overuse, mesquite (*Prosopis* L.), plains pricklypear (*Opuntia polyacantha* Haw.), and broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby) may become invaders (Bell, 1994). Annual forbs also become more abundant with overuse (Bell, 1994). This range cover type parallels the USDA-NRCS Deep Hardland or Clay Loam range sites (Bell, 1994).

The range site is "**Deep Hardland pz 25-34.**" The potential average annual production during normal years is 1750 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 1100 pounds per acre or less and, in favorable years, annual productions can reach 2400 pounds per acre (USDA, SCS, 1970 and 1980c).

Study sites **C1** and **C2** were selected because they represented two contrasting vegetative states that are common in the Grama-Buffalograss range cover type. The major contrasts between these two sites were the biomass production and species compositions. Study site **C1** was dominated by blue grama with some forbs, broom snakeweed, and pricklypear. Study site **C2** was composed of nearly equal portions of blue grama and buffalograss with very few other species on the site. The level of production of study site **C2** was considerably less than that of study site **C1**. Standing dead grass was also considerably less on study site **C2** than on study site **C1**. In the site selection process, it did not appear that the ground cover or litter differed significantly between the study sites.

Climate

The climate is cool temperate, with alternately mild and very cool winter days and hot summers. Air temperatures may change rapidly during the day. Rainfall is most often the result of thunderstorms (USDA, SCS, 1970). The annual average precipitation at Vega, TX (Oldham Co.) is approximately 18 inches. Average annual snowfall is 21 inches. Seventy percent of precipitation usually occurs between April and September. The growing season is 155 days in 9 out of 10 years. The earliest frost (air temperature 32° F or lower) is October 21, and the latest frost is May 9 in 5 out of 10 years (USDA, SCS, 1980c).

Soils

Soils at the two study sites sampled in Texas were in the Olton series. The Olton series is classified as a fine, mixed, thermic Aridic Paleustolls. The Olton series consists of deep, well drained, moderately slowly permeable soils that form in calcareous loamy eolian deposits on the High Plains (USDA, SCS, 1980c). The NSSL pedon numbers for the representative soil pedon at each site are 90P0855 and 90P0860 for study sites **C1** and **C2**, respectively. Some selected soil chemical and physical properties are presented in Tables 1a, 1b, 2a, and 2b for study sites **C1** and **C2** in Texas.

Bulk density was sampled on six plots at each study site, using either the compliant cavity or the balloon excavation methods. Bulk density was measured at three positions and two depths before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **C1** and **C2**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **C1** were **78.2%** and **11.9%,** respectively. The respective values at study site **C2** were **54.0%** and **12.1%.**

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 90P0855 at study site **C1** in Texas.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-3	SIL	26.5	52.7	20.8	0.99	-1/
A2	3-15	L	36.6	39.1	24.3	1.45	-
Bt1	15-38	CL	33.3	33.9	32.8	1.67	-
Bt2	38-68	CL	30.3	37.4	32.3	1.69	-
Bt3	68-92	L	37.1	37.8	25.1	1.56	-
Bt4	92-113	L	45.2	30.2	24.6	1.55	-
Btk1	113-145	CL	21.2	41.7	37.1	1.65	-
Btk2	145-161	SICL	19.5	46.9	33.6	1.68	-

1/ measure not taken on sample

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 90P0860 at study site **C2** in Texas.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-3	SIL	26.6	50.3	23.1	1.31	-
A2	3-20	L	42.8	34.1	23.1	1.50	-
Bt1	20-33	CL	36.9	28.2	34.9	1.67	-
Bt2	33-56	CL	30.6	33.5	35.9	1.69	-
Bt3	56-84	CL	27.7	35.9	36.4	1.77	1
Bt4	84-117	CL	29.6	38.6	31.8	1.61	Tr 2/
Btk1	117-140	CL	26.1	35.2	38.7	1.58	8
Btk2	140-150	CL	22.6	38.2	39.2	1.59	3

2/ Tr = Trace Amount

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 90P0855 at study site **C1** in Texas.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-3	3.45	0.21	0.13	18.4	6.6
A2	3-15	1.59	0.12	0.12	17.6	6.6
Bt1	15-38	1.00	0.08	0.14	21.8	7.0
Bt2	38-68	0.28	-.--	0.13	20.7	7.8
Bt3	68-92	0.18	-.--	0.15	17.5	8.2
Bt4	92-113	0.13	-.--	0.17	16.3	8.3
Btk1	113-145	0.18	-.--	0.14	12.6	8.6
Btk2	145-161	0.12	-.--	0.16	14.0	8.3

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 90P0860 at study site **C2** in Texas.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-3	3.04	0.22	0.13	19.6	5.7
A2	3-20	1.58	0.12	0.12	16.6	6.3
Bt1	20-33	1.07	0.09	0.13	21.6	6.9
Bt2	33-56	0.66	0.07	0.14	21.3	7.6
Bt3	56-84	0.29	-.--	0.13	21.7	8.2
Bt4	84-117	0.19	-.--	0.15	20.6	8.2
Btk1	117-140	0.20	-.--	0.15	15.1	8.3
Btk2	140-150	0.18	-.--	0.14	12.3	8.3

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in Texas.

Sample time and depth	**Site C1**	**Site C2**
before dry run, 0-1"	0.76	1.08
before dry run, 1-4"	1.27	1.39
before dry run, 0-4" (weighted average)	1.14	1.31
after very wet run, 0-1"	0.75	0.94
after very wet run, 1-4"	1.27	1.41
after very wet run, 0-4" (weighted average	1.14	1.29

Management History

Study site **C1** is located in a 1200-acre field. It is used for cow-calf grazing from summer through fall. Grazing management includes rotation to other pastures. The landowner leases the 640-acre pasture for grazing where study site **C2** is located. Study site **C2** is intensely grazed. It is used for a cow-calf and yearling pasture from summer through fall, but there is no grazing system or rotation being applied. Neither study site has had any mechanical treatments, brush control, prescribed burning, or fertilization.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values.

Below ground root biomass was also measured for all plots at each study site. A relatively uniformly spaced plant community with no interspaces was present at the sites, therefore, only a single type of representative area was sampled at the two study sites in Texas. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site.

Table 4. Canopy and ground cover (%) for study sites in Texas.

Cover category	Site C1	Site C2
Grass	9.8	8.9
Forb	1.1	0.0
Shrub	0.1	0.0
Cactus	0.4	0.0
Half-Shrub	0.0	0.0
Standing Dead	11.7	1.4
Total canopy cover	**23.1**	**10.4**
Basal vegetation	13.8	3.0
Cryptogam <1cm	0.0	0.0
Cryptogam >1cm	0.0	0.0
Litter	83.2	83.7
Rock	0.0	0.0
Bare soil	3.0	13.3
Total ground cover	**97.0**	**86.7**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Texas sites. Value of 0.0 denotes an absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site C1	Site C2
Native grasses and sedges		
blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)	970.5	248.1
buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.)	140.6	260.5
Total of native grasses and sedges	**1111.1**	**508.6**

Table 5 continued

Native forbs and other herbaceous plants		
upright prairie coneflower (*Ratibida columnifera* (Nutt.) Woot. & Standl.)	39.6	0.0
curlycup gumweed (*Grindelia squarrosa* (Pursh) Dunal)	33.3	0.0
rush skeletonplant (*Lygodesmia juncea* (Pursh) D. Don ex Hook.)	17.5	0.0
scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb.)	5.0	0.0
wavyleaf thistle (*Cirsium undulatum* (Nutt.) Spreng.)	3.8	0.0
spurge (*Euphorbia* L.)	2.5	0.0
Virginia pepperweed (*Lepidium virginicum* L.)	0.0	Tr
Total of native forbs and other herbaceous plants	**101.8**	**0.0**
Native shrubs and cacti		
pricklypear (*Opuntia* P. Mill.)	55.8	1.5
broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby)	45.1	0.0
Total of native shrubs and cacti	**101.0**	**1.5**
Introduced forbs and other herbaceous plants		
other annual forb	17.1	0.0
meadow salsify (*Tragopogon pratensis* L.)	0.0	Tr
Total of introduced forbs and other herbaceous plants	**17.1**	**0.0**
Total average live plant annual yield	**1331.1**	**510.1**
Soil surface residue and standing dead plant material		
non-woody litter	2383.1	1694.3
standing-dead grass	1244.1	333.0
Total of soil surface residue and standing dead plant material	**3627.3**	**2027.3**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Texas.

Sample depth	Site C1	Site C2
0-1"	7008.3	7172.0
1-4"	3254.1	4196.2
0-4" (total)	10262.4	11368.2

Hydrology

All 36 plot runs in Texas were considered suitable for inclusion in analyses. Initial rainfall abstraction could not be calculated for wet plot-runs at site **C2** or very wet plot-runs at site **C1**. The sample size for average of initial rainfall abstraction was not 6 for any of the replicated plot-runs at either site.

Table 7. Hydrology Results for study sites in Texas. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site C1	Site C2
Dry plot-runs at antecedent soil moisture		
Total rainfall (mm)	53.66	55.59
Uniform rainfall rate (mm h^{-1})	53.66	55.59
Rainfall duration (minutes)	60.00	60.00
Total runoff (mm)	6.80	24.40
Runoff to rainfall ratio (mm mm^{-1})	0.13	0.44
Time to start of runoff (minutes)	18.78	13.82
Peak runoff rate (mm h^{-1})	12.73	40.76
Time to peak runoff (minutes)	55.00	53.00
Initial abstraction depth (mm)	2.12	4.42
Recession depth (mm)	0.63	3.25
Total sediment yield (kg ha^{-1})	68.72	235.58
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	9.76	9.96
Equilibrium infiltration rate (mm h^{-1})	41.73	14.82
Wet plot-runs 24 h after dry plot-runs		
Total rainfall (mm)	29.72	28.30
Uniform rainfall rate (mm h^{-1})	58.14	58.59
Rainfall duration (minutes)	30.67	29.00
Total runoff (mm)	4.30	12.78
Runoff to rainfall ratio (mm mm^{-1})	0.14	0.46
Time to start of runoff (minutes)	13.71	8.59
Peak runoff rate (mm h^{-1})	18.36	42.42
Time to peak runoff (minutes)	27.83	23.33
Initial abstraction depth (mm)	4.66	-.- _
Recession depth (mm)	1.01	3.86
Total sediment yield (kg ha^{-1})	48.31	78.40
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	11.23	6.15
Equilibrium infiltration rate (mm h^{-1})	40.43	19.91

Table 7 continued

Very wet plot-runs 30 minutes after wet plot-runs		
Total rainfall (mm)	52.85	60.15
Rainfall duration (minutes)	44.67	48.67
Total runoff (mm)	25.68	39.60
Runoff to rainfall ratio (mm mm^{-1})	0.49	0.66
Time to start of runoff (minutes)	7.65	2.56
Peak runoff rate (mm h^{-1})	74.81	81.41
Time to peak runoff (minutes)	33.33	31.50
Initial abstraction depth (mm)	-.-	1.78
Recession depth (mm)	2.54	4.30
Total sediment yield (kg ha^{-1})	164.08	148.15
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	6.35	3.94

– value not calculated or derived

NRST Rangeland Sites in Utah

Site Descriptions

Two sites, **M1** and **M2**, were sampled in Iron County, Utah, during June, 1993. Study sites **M1** (NE ¼ of SW ¼ of S27 T35S R13W, 37° 43′ 35″ N, 113° 18′ 4″ W) and **M2** (SW ¼ of NW ¼ of S34 T35S R13W, 37° 42′ 48″ N, 113° 18′ 16″ W) were approximately 12 miles WNW of Cedar City, UT. Study sites **M1** and **M2** were less than a mile apart. The following descriptions apply to both sites unless otherwise noted. The relevant SWCD is the E and I. The local NRCS office is the Cedar City Field Office. The Major Land Resource Area is the Great Salt Lake Area (MLRA No. 28A) of the Western Range and Irrigated Region. About 75% of this MLRA is federally managed and principally is used for rangeland livestock production (USDA, SCS, 1981). Because the production of the native shrubs and grasses is very low, the extent of the livestock industry is determined by the availability of hay, pasture, and grain that can be grown under irrigation (USDA, SCS, 1981). Where annual precipitation is between 200-300 mm, like near Cedar City, the vegetation characteristically would be dominated by shrubs such as big sagebrush (*Artemisia tridentata* Nutt.), shadscale (*Atriplex confertifolia* (Torr. & Frem.) S. Wats.[=shadscale saltbush]) , winterfat (*Kraschenninnikovia lanata* (Pursh) Guldenstaedt), and associated grasses such as bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Love), Indian ricegrass (*Oryzopsis hymenoides* (Roemer & J.A. Schultes) Ricker ex Piper), and bluegrasses (*Poa* L.) (USDA, SCS, 1981).

The range cover type is Wyoming Big Sagebrush of the Great Basin Region. This cover type, characterized by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle & Young), is the largest and most xeric of the big sagebrush range cover types (Tisdale, 1994). Principal understory include the perennial bunchgrasses, bluebunch wheatgrass, and Sandberg's bluegrass (*Poa secunda* J. Presl). Other perennial grasses such as bottlebrush squirreltail (*Elymus elymoides* (Raf.) Swezey), Thurber needlegrass (*Achnatherum thurberianum* (Piper) Barkworth), needleandthread (*Stipa comata* Trin. & Rupr.), Indian ricegrass, and rhizomatous wheatgrasses also may dominant the understory of some sites (Tisdale, 1994). Large areas of this cover type have been converted to annual grasslands dominated by cheatgrass (*Bromus tectorum* L.) as a result of various combinations of grazing and fire (Tisdale, 1994).

The range site is **Semidesert Loam**. The historic climax plant community of this site would be Wyoming big sagebrush and bluebunch wheatgrass (USDA, SCS, 1988). Composition by air-dry weight would be 55% grasses, 5% forbs, and 45% shrubs. The potential average annual production during normal years is 650-700 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 450-500 pounds per acre or less and, in favorable years, annual productions can reach 850-900 pounds per acre (USDA, SCS, 1988).

Study sites **M1** and **M2** were selected because they represent two contrasting vegetation states that are relevant to the southern portion of the Wyoming Big Sagebrush range cover type. Study site **M1** was dominated by Wyoming big sagebrush, with a small amount of grasses in the understory. Study site **M2** had been chemically treated for brush management three years prior to sampling and was dominated by galleta grass at the time of sampling, with only a small amount of sagebrush left on the site. Study site **M1** had significantly more surface mulch then site **M2**, but the amount of bare soil appeared to be about equal.

Climate

Annual average precipitation at Cedar City, UT is 10.64 inches. Average annual snowfall is 45.2 inches. The coolest month is January with an average daily minimum of 17.2 °F. The warmest month is July with an average daily maximum of 90.0 °F (WRRC, 1997b). For the Taylors Flat soil series, the mean

annual soil temperature is 47-53 °F. The annual frost free period is 110-140 days. The average annual precipitation is 9-12 inches.

Soils

Soils at both sites are in the Taylors Flat series. These soils are classified as fine-loamy, mixed, mesic Xeric Haplocalcids. The soil at study sites **M1** and **M2** developed on an alluvial fan derived from alluvium from basic igneous rocks over alluvium from intermediate igneous rocks. The NSSL pedon numbers for the representative soil pedon are 93P0720 and 93P0725 for sites **M1** and **M2**, respectively. Tables 1a, 1b, 2a, and 2b present some selected soil chemical and physical properties for study sites **M1** and **M2**.

Bulk density was sampled on six plots at each study site, using the balloon excavation method. Bulk density was measured at three positions and two depths before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **M1** and **M2**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **M2** were **4.5%** and **0.7%**, respectively. Aggregate stability values are unavailable for study site **M1.**

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 93P0720 at study site **M1** in Utah.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-5	SL	71.0	20.5	8.5	-.-- 1/	64
A2	5-20	FSL	58.2	25.6	16.2	1.32	17
Bw	20-32	FSL	54.6	25.8	19.6	1.48	16
Bk1	32-51	L	46.1	34.2	19.7	1.44	18
Bk2	51-97	FSL	63.6	26.2	10.2	1.59	8
Bkm	97-101	SL	70.0	21.6	8.4	-.--	-
2C	101-169	FSL	65.2	32.4	2.4	1.64	3
3C	169-200	COSL	77.5	11.0	11.5	-.--	68

1/ measure not taken on sample

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 93P0725 at study site **M2** in Utah.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A1	0-4	SL	69.8	21.7	8.5	-.--	22
A2	4-17	FSL	60.3	25.2	14.5	1.48	14
Bw	17-28	FSL	53.4	26.7	19.9	1.40	17
Bk1	28-51	FSL	52.3	31.6	16.1	1.47	23
Bk2	51-80	L	42.5	37.2	20.3	1.39	-
Bk3	80-107	L	44.7	29.9	25.4	1.57	6
2C	107-137	LS	80.5	9.8	9.7	-.--	47
3Ck	137-200	L	41.8	33.9	24.3	1.47	26

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 93P0720 at study site **M1** in Utah.

Horizon	Horizon depths (cm)	Organic carbon [1/] (%)	Total [2/] Nitrogen (%)	Water retention difference [3/] (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-5	0.60	0.08	Tr	11.5	7.5
A2	5-20	0.65	0.09	0.09	10.0	8.2
Bw	20-32	0.62	0.08	0.16	7.9	8.2
Bk1	32-51	0.32	0.06	0.19	5.3	8.3
Bk2	51-97	0.28	0.04	0.15	6.3	8.8
Bkm	97-101	0.29	-.--	Tr	8.6	8.8
2C	101-169	0.06	-.--	0.10	12.0	8.7
3C	169-200	0.04	-.--	Tr	10.3	8.7

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 93P0725 at study site **M2** in Utah.

Horizon	Horizon depths (cm)	Organic carbon [1/] (%)	Total [2/] Nitrogen (%)	Water retention difference [3/] (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A1	0-4	1.47	0.17	Tr	11.1	7.4
A2	4-17	0.76	0.08	0.08	9.4	7.9
Bw	17-28	0.71	0.09	0.11	8.7	8.0
Bk1	28-51	0.25	0.04	0.18	6.4	8.3
Bk2	51-80	0.19	0.04	0.14	9.9	8.7
Bk3	80-107	0.09	-.--	0.13	6.9	9.0
2C	107-137	0.03	-.--	Tr	9.5	9.1
3Ck	137-200	0.09	-.--	0.10	9.6	8.6

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when adjusted for salt and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in Utah.

Sample time and depth	**Site M1**	**Site M2**
before dry run, 0-1"	1.19	1.95
before dry run, 1-4"	0.93	1.29
before dry run, 0-4" (weighted average)	0.99	1.45
after very wet run, 0-1"	1.80	1.33
after very wet run, 1-4"	1.01	1.27
after very wet run, 0-4" (weighted average	1.20	1.29

Management History

Study site **M1** is leased for grazing from the Bureau of Land Management, Cedar City Field Office. The area sampled is in a 1350-acre pasture that was open range approximately 50 years ago. Grazing is by cow and calf, yearlings, and native antelope. Livestock grazing occurs in winter and spring in a rotational deferred system. No range treatments have been applied in this pasture. Study site **M2** is on privately owned land. The area is located in a 625-acre pasture. Prior to 30 years ago, the area was intensively grazed. Beginning about 10-20 years ago, the grazing intensity was reduced. Current grazing is by yearling cattle and native antelope. Livestock grazing is 220 animal unit months per year during winter and spring. No grazing system is used. The area was chemically treated with "Spike 20p," 0.45 pounds active ingredient per acre, aerially applied, in June of 1990 to reduce sagebrush cover. The brush control treatment was 98% effective.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values.

Below ground root biomass also was measured for all plots at each study site. Areas in plant interspaces and under plant canopies were sampled separately at study sites **M1** and **M2**. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site and surface type.

Table 4. Canopy and ground cover (%) for study sites in Wyoming.

Cover category	**Site M1**	**Site M2**
Grass	3.0	25.3
Forb	2.1	4.7
Shrub	20.6	1.1
Cactus	0.1	0.2
Half-Shrub	0.0	0.0
Standing Dead	2.7	21.0
Total canopy cover	**28.4**	**52.4**
Basal vegetation	1.4	2.1
Cryptogam <1cm	0.0	0.0
Cryptogam >1cm	0.1	0.3
Litter	29.5	37.0
Rock	9.4	2.4
Bare soil	59.6	58.2
Total ground cover	**40.4**	**41.8**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Utah sites. Value of 0.0 denotes an absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site M1	Site M2
Native grasses and sedges		
bottlebrush squirreltail (*Elymus elymoides* (Raf.) Swezey)	30.1	34.5
galleta (*Hilaria jamesii* (Torr.) Benth.)	10.0	454.3
purple threeawn (*Aristida purpurea* Nutt.)	3.1	80.8
indian ricegrass (*Oryzopsis hymenoides* (Roemer & J.A. Schultes) Ricker ex Piper)	0.6	1.5
needleandthread grass (*Stipa comata* Trin. & Rupr.)	0.6	10.0
blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)	0.0	3.1
Sandberg bluegrass (*Poa secunda* J. Presl)	0.0	Tr
sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray)	Tr	19.1
Total of native grasses and sedges	**44.6**	**603.5**
Native forbs and other herbaceous plants		
rose heath (*Chaetopappa ericoides* (Torr.) Nesom)	6.6	0.0
gooseberryleaf globemallow (*Sphaeralcea grossulariifolia* (Hook. & Arn.) Rydb)	3.0	2.8
whitestem blazingstar (*Mentzelia albicaulis* (Dougl. ex Hook.) Dougl. ex Torr. & Gray)	2.6	30.1
longleaf phlox (*Phlox longifolia* Nutt.)	1.1	0.6
hoary townsendia (*Townsendia incana* Nutt.)	0.3	Tr
specklepod milkvetch (*Astragalus lentiginosus* Dougl. ex Hook.)	0.1	5.5
lambsquarters (*Chenopodium album* L.)	0.0	0.1
cryptantha (*Cryptantha* Lehm. ex G. Don)	0.0	Tr
shaggy fleabane (*Erigeron pumilus* Nutt.)	0.0	Tr
stickseed (*Hackelia* Opiz)	0.0	19.0
western tansymustard (*Descurainia pinnata* (Walt.) Britt.)	Tr	10.3
Palmer's buckwheat (*Eriogonum palmerianum* Reveal)	Tr	2.6
sand gilia (*Gilia leptomeria* Gray)	Tr	0.0
spurge (*Euphorbia* L.)	Tr	0.0
Total of native forbs and other herbaceous plants	**14.0**	**71.3**
Native shrubs and cacti		
Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle & Young)	403.8	18.5
broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby)	1.1	Tr
fishhook cactus (*Sclerocactus* Britt. & Rose)	0.0	Tr
green rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.)	0.0	0.3
Total of native shrubs and cacti	**405.0**	**18.8**
Introduced grasses		
cheatgrass (*Bromus tectorum* L.)	Tr	0.5
Total of introduced grasses	**Tr**	**0.5**
Total average live plant annual yield	**463.6**	**694.1**

Table 5 continued		
Soil surface residue and standing dead plant material		
non-woody litter	4936.1	2717.3
standing-dead grass	1173.6	24.5
standing-live wood	1058.3	0.0
standing-dead wood	0.0	2612.1
Total of soil surface residue and standing dead plant material	**7168.1**	**5354.0**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Utah.

	Under Plant Canopy[1/]		Plant Interspace[2/]	
Sample depth	**Site M1**	**Site M2**	**Site M1**	**Site M2**
0-1"	493.8	1835.4	283.6	329.9
1-4"	559.8	1161.8	348.6	414.0
0-4" (total)	1053.6	2997.2	632.2	743.9

1/ Samples taken in are under plant canopies.
2/ Samples taken in open area not under plant canopies.

Hydrology

There are 24 plot-runs available for analyses from the two sites in Utah. Measured sediment concentrations during the very wet plot-run of Plot 1 at site **M1** appears to be too high, although runoff appears normal. No correction could be applied. For this report, this plot-run has had total sediment yield and sediment yield to runoff ratio excluded from calculations of averages for the site. This has the effect of reducing the average total sediment yield of the very wet plot-runs at site **M1** by over two thirds.

Table 7. Hydrology results for study sites in Utah. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	**Site M1**	**Site M2**
Dry plot-runs at antecedent soil moisture		
Total rainfall (mm)	57.92	57.44
Uniform rainfall rate (mm h^{-1})	57.92	57.44
Rainfall duration (minutes)	60.00	60.00
Total runoff (mm)	2.65	0.57
Runoff to rainfall ratio (mm mm^{-1})	0.05	0.01
Time to start of runoff (minutes)	27.83	40.00
Peak runoff rate (mm h^{-1})	7.33	6.58
Time to peak runoff (minutes)	52.83	38.83
Initial abstraction depth (mm)	27.37	39.22
Recession depth (mm)	0.10	0.04
Total sediment yield (kg ha^{-1})	49.22	7.83
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	20.33	9.28
Equilibrium infiltration rate (mm h^{-1})	50.68	55.51

Table 7 continued

Wet plot-runs 24 h after dry plot-runs were not conducted in Utah		
Very wet plot-runs 30 minutes after wet plot-runs		
Total rainfall (mm)	82.96	132.80
Rainfall duration (minutes)	66.00	110.00
Total runoff (mm)	32.19	38.72
Runoff to rainfall ratio (mm mm^{-1})	0.40	0.29
Time to start of runoff (minutes)	3.19	9.49
Peak runoff rate (mm h^{-1})	68.28	65.09
Time to peak runoff (minutes)	42.33	84.67
Initial abstraction depth (mm)	3.64	10.13
Recession depth (mm)	0.47	0.66
Total sediment yield (kg ha^{-1})	593.36	811.86
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	16.58	19.93

– value could not be determined

NRST Rangeland Sites in Central Eastern Wyoming

Site Descriptions

Three mixed grass prairie sites, **G1, G2**, and **G3**, were sampled in Weston County, Wyoming, during July, 1991. Study sites **G2** and **G3** (NW ¼ of NE ¼ of S27 T44N R63W, 43° 45′ 00″ N, 104° 22′ 30″ W) were 8 miles SW of Newcastle, WY. Study sites **G2** and **G3** were less than 2 tenths of a mile apart. Study site **G1** (SW ¼ of SW ¼ of S29 T44N R63W, 43° 47′ 30″ N, 104° 47′ 30″ W) was 10 miles SW of Newcastle, WY. Study site **G1** was less than 2 ½ mile from study sites **G2** and **G3**. All three sites were located on land owned by Mr. William Townsend.

The following descriptions apply to all three sites unless otherwise noted. The relevant SWCD is Weston County, WY, and the NRCS office is the Newcastle Field Office in the Sheridan Area. The Major Land Resource Area is Pierre Shale Plains and Badlands (MLRA No. 60A) of the Western Great Plains Range and Irrigated Region. Most of this MLRA is in native grasses and is used for grazing (USDA, SCS, 1981). Characteristic mixed grass prairie vegetation includes western wheatgrass (*Pascopyrum smithii* [Rydb.] A. Love), green needlegrass (*Nassella viridula* [Trin.] Barkworth), blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), and buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.). Little bluestem (*Schizachyrium scoparium* [Michx.] Nash) and sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.) occur on shallow soils, and big bluestem (*Andropogon gerardii* Vitman) occurs along streams (USDA, SCS, 1981).

The range cover type is Wheatgrass-Grama-Needlegrass of the Northern Great Plains Region. The mid-grasses such as the wheatgrasses, needlegrasses, and prairie Junegrass (*Koeleria macrantha* [Ledeb.] J.A. Schultes) are still important or dominant in this range cover type. However, the short grasses such as blue grama, Sandberg's bluegrass (*Poa secunda* J. Presl), and several sedges frequently become the dominants. Blue grama and buffalograss have increased in this range cover type, due to grazing (Barker and Whitman, 1994e). Cheatgrass (*Bromus tectorum* L.) and Japanese brome (*Bromus japonicus* Thunb. ex Murr.) are common on deteriorated rangelands (Barker and Whitman, 1994e).

The range site is **Loamy**. The Loamy range site occurs on nearly level to 50% slopes at elevations between 3800 and 5100 feet. The historic climax plant community would be dominated by midgrasses. The percent composition by weight would be 75% grasses and grass-like plants, 15% forbs, and 10% woody plants. Dominant grasses by air-dry weight would be western wheatgrass, thickspike wheatgrass, needleandthread, and blue grama. The potential average annual production during normal years is 1200 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 700 pounds per acre or less and, in favorable years, annual productions can reach 1500 pounds per acre (USDA, SCS, 1990a).

Study sites **G1**, **G2**, and **G3** were selected because they represent three contrasting vegetation states that are relevant to the Wheatgrass-Grama-Needlegrass range cover type. All study sites were dominated by grasses when considering annual production, but there appeared to be significant differences between the sites. Study site **G1** was dominated as a whole by grasses, but the dominate individual species on this site was prickly pear cactus when considering annual production and, when looking at total biomass, prickly pear totally dominates the site. Prickly pear occurred on sites **G2** and **G3** but in much smaller amounts. Study site **G2** had more annual production than sites **G1** and **G3**, but the dominant species on site **G2** was cheatgrass, which did not occur on sites **G1** and **G3**. Study site **G3** had the lowest production of the three sites and was dominated by native perennial grasses and sedges, with only a small amount of prickly pear and no cheatgrass noted. Study site **G3** also had a significantly higher amount of bare ground then did sites **G1** and **G2**.

Climate

The average annual precipitation at Newcastle, WY, is 14.1 inches, of which 79% usually falls between April and September. The average seasonal snowfall is 37.1 inches. During winter, the average temperature is 25 °F and the average minimum temperature is 14 °F. In summer, the average temperature is 70 °F and the average maximum temperature is 84 °F. The average daily temperature is 46.7 °F. The frost free period (temperature greater then 32 °F) is May 15 to September 28 in 5 out of 10 years (USDA, SCS, 1990b).

Soils

Soils at all three sites are in the Kishona series. These soils are classified as fine-loamy, mixed (calcareous), mesic Ustic Torriorthents. The sampled sites were mapped as Kishona-Shingle-Theedle loams, 6 to 15 percent slopes (USDA, SCS, 1990b). The three soils are intricately intermingled. Kishona loam makes up 40% of the mapping unit. Kishona is deep and well drained and formed in alluvial sediment derived dominantly from sedimentary rock (USDA, SCS, 1990b). The NSSL pedon numbers for the representative soil pedon at each site are 91P0987, 91P0982, and 91P0977 for sites **G1**, **G2**, and **G3**, respectively. All three representative pedons formed in residuum of sandstone-shale sedimentary rocks. Tables 1a, 1b, 1c, 2a, 2b, and 2c present some selected soil chemical and physical properties for study sites **G1**, **G2**, and **G3**.

Bulk density was sampled on six plots at each study site, using either the compliant cavity or the balloon excavation method. Bulk density was measured at three positions and two depths before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **G1**, **G2**, and **G3**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **G1** were **34.0%** and **9.6%**, respectively. The respective values at study site **G2** were **41.8%** and **15.6%** and for study site **G3** were **11.0%** and **5.2%.**

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 91P0987 at study site **G1** in Wyoming.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry ($g\ cm^{-3}$)	Coarse fragments (% by weight)
A	0-14	VFSL	58.1	30.5	11.4	1.30	- 1/
Bw1	14-48	L	48.5	29.1	22.4	1.37	-
Bk1	48-71	L	43.7	32.4	23.9	1.42	1
Bk2	71-97	L	42.6	35.3	22.1	1.45	-
Bk3	97-115	L	49.9	30.0	20.1	1.52	-
Akb	115-136	L	49.2	30.4	20.4	1.49	-
Bkb	136-140	L	48.3	32.2	19.5	1.46	-

1/ measure not taken on sample

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 91P0982 at study site **G2** in Wyoming.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-14	L	47.1	29.2	23.7	1.38	-
AB	14-36	VFSL	64.8	21.0	14.2	1.45	-
Bw	36-63	VFSL	72.8	15.1	12.1	1.57	Tr 2/
Ab	63-88	VFSL	58.1	23.2	18.7	1.41	-
Bwb	88-107	L	44.9	31.1	24.0	1.40	Tr
Bk1	107-130	SCL	50.5	27.4	22.1	1.43	-
Bk2	130-155	VFSL	58.1	23.0	18.9	-.--	-

2/ Tr = Trace Amount

Table 1c. Some selected soil properties of National Soil Survey Laboratory pedon number 91P0977 at study site **G3** in Wyoming.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-10	VFSL	60.1	26.3	13.6	1.25	-
Bw1	10-24	VFSL	66.0	20.8	13.2	1.48	Tr
Bw2	24-41	VFSL	64.6	22.0	13.4	1.51	Tr
C1	41-72	VFSL	61.1	22.9	16.0	1.54	Tr
C2	72-100	VFSL	57.5	24.8	17.7	1.43	2
C3	100-117	VFSL	54.6	25.9	19.5	-.--	31
Cr	117-158	SICL	16.4	49.0	34.6	-.--	-

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 91P0987 at study site **G1** in Wyoming.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-14	1.29	-	0.14	8.6	7.3
Bw1	14-48	0.66	-	0.09	16.0	7.9
Bk1	48-71	0.60	-	0.13	12.9	7.9
Bk2	71-97	0.39	-	0.10	12.4	8.6
Bk3	97-115	0.26	-	0.12	12.1	8.9
Akb	115-136	0.23	-	0.10	12.6	8.8
Bkb	136-140	0.23	-	0.16	12.3	8.7

1/ Walkley-Black

2/ Kjeldahl

3/ Converts to available water capacity (AWC) when corrected for salts and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 91P0982 at study site **G2** in Wyoming.

Horizon	Horizon depths (cm)	Organic carbon [1/] (%)	Total [2/] Nitrogen (%)	Water retention difference [3/] (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-14	1.76	-	0.24	18.0	7.8
AB	14-36	0.57	-	0.16	10.2	8.2
Bw	36-63	0.38	-	0.16	7.8	8.3
Ab	63-88	0.70	-	0.07	13.8	8.3
Bwb	88-107	0.69	-	0.15	15.8	8.5
Bk1	107-130	0.50	-	0.14	14.3	8.5
Bk2	130-155	0.30	-	Tr	13.9	8.6

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when corrected for salts and rock fragments, neither of which are significant for this pedon.

Table 2c. Additional selected soil properties of National Soil Survey Laboratory pedon number 91P0977 at study site **G3** in Wyoming.

Horizon	Horizon depths (cm)	Organic carbon [1/] (%)	Total [2/] Nitrogen (%)	Water retention difference [3/] (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-10	1.30	-	0.11	15.2	7.7
Bw1	10-24	0.64	-	0.11	12.9	8.3
Bw2	24-41	0.43	-	0.11	13.0	8.3
C1	41-72	0.24	-	0.09	14.2	8.7
C2	72-100	0.21	-	0.14	15.3	9.3
C3	100-117	0.21	-	Tr	17.0	8.4
Cr	117-158	0.17	-	Tr	23.0	7.9

1/ Walkley-Black
2/ Kjeldahl
3/ Converts to available water capacity (AWC) when corrected for salts and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in Wyoming.

Sample time and depth	**Site G1**	**Site G2**	**Site G3**
before dry run, 0-1"	0.72	0.94	0.77
before dry run, 1-4"	1.29	1.31	1.23
before dry run, 0-4" (weighted average)	1.15	1.21	1.11
after very wet run, 0-1"	0.99	0.76	0.81
after very wet run, 1-4"	1.35	1.27	1.29
after very wet run, 0-4" (weighted average	1.26	1.14	1.17

Management History

Study site **G1** was located in a 2816-acre field. Prior to 15 years before sampling, this rangeland was intensively grazed by both sheep and cattle. Current management is cow-calf grazing in a rotational grazing system. Season of use is spring, summer, or fall in rotation. No range treatments or prescribed burning have occurred at this study site. Study sites **G2** and **G3** were located in the same 4326-acre field. Prior to 15 years before sampling, the study sites were intensively used as a cattle wintering ground and for calving. Current management is cow-calf and some horse grazing in a year-round rotational grazing system. No known range treatments or burning have occurred at these sites.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values. Annual production of pricklypear (*Opuntia* P. Mill.) was assumed to be 10% of standing live biomass.

Below ground root biomass was also measured for all plots at each study site. Areas in plant interspaces and under plant canopies were sampled separately at the three study sites in Wyoming. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site and surface type.

Table 4. Canopy and ground cover (%) for study sites in Wyoming.

Cover category	Site G1	Site G2	Site G3
Grass	6.0	53.9	27.6
Forb	1.0	0.9	2.5
Shrub	0.1	0.1	0.1
Cactus	2.9	0.6	0.4
Half-Shrub	0.0	0.0	0.0
Standing Dead	0.9	0.2	1.7
Total canopy cover	**10.8**	**55.7**	**32.4**
Basal vegetation	11.8	3.1	8.2
Cryptogam <1cm	24.6	0.1	5.6
Cryptogam >1cm	0.2	0.1	0.4
Litter	40.1	77.7	32.2
Rock	0.0	0.0	0.4
Bare soil	23.2	19.0	53.2
Total ground cover	**76.8**	**81.0**	**46.8**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Wyoming sites. Value of 0.0 denotes an absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	Site G1	Site G2	Site G3
Native grasses and sedges			
needleandthread grass (*Stipa comata* Trin. & Rupr.)	385.8	453.1	276.4
threadleaf sedge (*Carex filifolia* Nutt.)	228.4	125.0	304.4
blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)	69.8	422.6	113.7
western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love)	51.1	57.3	24.5
sixweeks fescue (*Vulpia octoflora* (Walt.) Rydb.)	25.3	Tr	0.0
Sandberg bluegrass (*Poa secunda* J. Presl)	0.0	Tr	0.0
dropseed (*Sporobolus asper* (Beauv.) Kunth)	0.0	0.0	Tr
sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray)	0.0	45.4	3.0
Total of native grasses and sedges	**760.5**	**1103.6**	**722.2**
Native forbs and other herbaceous plants			
scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb.)	0.5	2.4	5.3
pepperweed (*Lepidium* L.)	0.0	3.2	0.0
milkvetch (*Astragalus* L.)	0.0	0.0	34.5
American vetch (*Vicia americana* Muhl. ex Willd.)	0.0	Tr	0.0
common pepperweed (*Lepidium densiflorum* Schrad.)	Tr	0.0	0.0
woolly plantain (*Plantago patagonica* Jacq.)	Tr	Tr	0.0
Total of native forbs and other herbaceous plants	**0.5**	**5.6**	**39.8**
Native shrubs and cacti			
pricklypear (*Opuntia* P. Mill.)	39.2	6.6	4.1
big sagebrush (*Artemisia tridentata* Nutt.)	Tr	0.0	Tr
Total of native shrubs and cacti	**39.2**	**6.6**	**4.1**
Introduced grasses			
Japanese brome (*Bromus japonicus* Thunb. ex Murr.)	1.8	0.0	0.0
cheatgrass (*Bromus tectorum* L.)	0.0	762.9	0.0
Total of introduced grasses	**1.8**	**762.9**	**0.0**
Introduced forbs and other herbaceous plants			
yellow sweetclover (*Melilotus officinalis* (L.) Lam.)	0.0	Tr	0.0
other annual forb	0.0	0.0	Tr
other perennial forb	0.0	Tr	Tr
Total of introduced forbs and other herbaceous plants	0.0	0.0	0.0
Total average live plant annual yield	**802.2**	**1878.8**	**766.3**
Soil surface residue and standing dead plant material			
non-woody litter	422.8	1043.9	173.6
standing-dead grass	39.3	20.9	36.0
Total of soil surface residue and standing dead plant material	**462.2**	**1064.9**	**209.6**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Wyoming.

	Under Plant Canopy[1/]			Plant Interspace[2/]		
Sample depth	Site G1	Site G2	Site G3	Site G1	Site G2	Site G3
0-1"	14544.9[3/]	4787.7	6133.6	6524.3[3/]	875.1[4/]	575.3
1-4"	7343.5[3/]	3191.9	7652.8	2911.4[3/]	729.4[4/]	2365.2
0-4" (total)	21888.4	7979.5	13789.4	9435.7	1604.5	2940.5

1/ Samples taken in areas under plant canopies.
2/ Samples taken in open areas not under plant canopies.
3/ only 3 plots were sampled
4/ only 2 plots were sampled

Hydrology

Fifty three of the fifty four plot-runs in northeast Wyoming were considered suitable to be included in analyses. Plot 3 at site **G1** had a headwall failure and so the plot-run was abandoned. Three of the dry plot-runs at site **G1** and two of the dry plot-runs at site **G2** had less than 1 mm total runoff. Plot-runs with less than 1 mm total runoff may be considered within the region of measurement error and should be considered potentially 0 mm runoff. The inclusion of these plot-runs will depend on the specific analysis. The interval between dry runs and wet runs at all three study sites was greater than 24 hours for all but two of the plot-runs. This does not invalidate the results but suggests that they may not be suitable without adjustment for comparison with other study sites where the interval was the proscribed 24 hours. Table 7 presents a summary of some pertinent hydrologic results.

Table 7. Hydrology Results for study sites in Wyoming. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site G1	Site G2	Site G3
Dry plot-runs at antecedent soil moisture			
Total rainfall (mm)	49.18	56.51	57.03
Uniform rainfall rate (mm h^{-1})	49.18	56.51	57.03
Rainfall duration (minutes)	60.00	60.00	60.00
Total runoff (mm)	2.29	2.79	17.45
Runoff to rainfall ratio (mm mm^{-1})	0.04	0.05	0.30
Time to start of runoff (minutes)	10.17	6.89	6.75
Peak runoff rate (mm h^{-1})	5.13	5.93	27.27
Time to peak runoff (minutes)	35.83	25.67	46.67
Initial abstraction depth (mm)	8.64	6.67	6.78
Recession depth (mm)	0.05	0.07	1.00
Total sediment yield (kg ha^{-1})	21.33	29.63	293.07
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	7.34	12.70	17.29
Equilibrium infiltration rate (mm h^{-1})	54.86	51.20	32.61

Table 7 continued

Wet plot-runs 24 h after dry plot-runs			
Total rainfall (mm)	48.87	39.81	33.80
Uniform rainfall rate (mm h^{-1})	54.01	59.02	58.62
Rainfall duration (minutes)	55.33	40.67	34.67
Total runoff (mm)	4.29	2.45	12.89
Runoff to rainfall ratio (mm mm^{-1})	0.10	0.06	0.38
Time to start of runoff (minutes)	16.14	8.93	6.47
Peak runoff rate (mm h^{-1})	14.23	8.63	36.38
Time to peak runoff (minutes)	51.33	35.33	30.67
Initial abstraction depth (mm)	14.70	8.91	6.53
Recession depth (mm)	0.57	0.20	1.62
Total sediment yield (kg ha^{-1})	75.55	17.66	134.53
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	19.58	7.60	10.87
Equilibrium infiltration rate (mm h^{-1})	41.20	52.64	25.16

Very wet plot-runs 30 minutes after wet plot-runs			
Total rainfall (mm)	70.97	69.74	81.60
Rainfall duration (minutes)	62.00	58.67	61.33
Total runoff (mm)	27.13	18.90	57.28
Runoff to rainfall ratio (mm mm^{-1})	0.38	0.27	0.71
Time to start of runoff (minutes)	15.27	7.21	3.91
Peak runoff rate (mm h^{-1})	61.94	53.42	97.08
Time to peak runoff (minutes)	36.20	33.50	40.17
Initial abstraction depth (mm)	15.53	7.33	4.31
Recession depth (mm)	0.48	0.41	2.17
Total sediment yield (kg ha^{-1})	442.19	185.25	442.34
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	19.08	10.08	8.25

NRST Rangeland Sites in Northeastern Wyoming

Site Descriptions

Two study sites, **I1** and **I2**, were sampled in Johnson County, Wyoming, during July, 1992. Study site **I1** (SE ¼ of SW ¼ of S31 T51N R80W, 44° 20′ 32″ N, 106° 31′ 38″ W) and **I2** (SE ¼ of SW ¼ of S31 T51N R80W, 44° 20′ 38″ N, 106° 31′ 38″ W) were 10 miles east of Buffalo, WY. These two study sites were on lands administered by the Bureau of Land Management, Casper District, Buffalo Area. The relevant SWCD is Lake DeSmet, Johnson County, WY. The relevant NRCS offices is the Buffalo Field Office. The Major Land Resource Area is Northern Rolling High Plains, Southern Part (**MLRA No. 58B**) of the Western Great Plains Range and Irrigated Region. Nearly 80% of this MLRA is in native shrubs and grasses grazed by cattle and sheep (USDA, SCS, 1981).

The range cover type for study site **I1** and **I2** is Sagebrush-Grass of the Northern Great Plains Region. This range cover type is fragmented and of limited extent and occurs as inclusions in the Wheatgrass-Grama-Needlegrass and Wheatgrass-Needlegrass range cover types (Barker and Whitman, 1994e and 1994f). The dominant shrub is big sagebrush (*Artemisia tridentata* Nutt.). Dwarf sagebrush (*Artemisia cana* Pursh [=silver sagebrush]) and rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt. and *Chrysothamnus nauseosus* ssp. *nauseosus* [Pallas ex Pursh] Britt.) also often occur (Barker and Whitman, 1994d).

The range site is **Loamy**. The Loamy range site occurs on nearly level to 50% slopes at elevations between 3800 and 5100 feet. The historic climax plant community would be dominated by mid-grasses. The percent composition by weight would be 75% grasses and grass-like plants, 15% forbs, and 10% woody plants. Dominant grasses by air-dry weight would be western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), thickspike wheatgrass (Elymus macrourus (Turcz.) Tzvelev), needleandthread (*Stipa comata* Trin. & Rupr.), and blue grama. The potential average annual production during normal years is 1200 pounds per acre, air dry weight. During unfavorable years, annual production may drop to 700 pounds per acre or less and, in favorable years, annual productions can reach 1500 pounds per acre (USDA, SCS, 1990a). Soils are moderately deep to very deep, well drained, and permeable.

Study sites **I1** and **I2** were selected because they represent two very contrasting vegetation states that are relevant to the Wheatgrass-Grama-Needlegrass and the Sagebrush-Grass range cover types in the Northern Great Plains Region. These study sites are also relevant to the eastern portion of the Wyoming Big Sagebrush range cover type of the Great Basin Region. Study site **I1** was dominated by Wyoming big sagebrush with small amounts of grasses such as western wheatgrass, green needlegrass (*Stipa viridula* Trin.), bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *spicata* [Pursh] A. Love), and prairie Junegrass scattered throughout the plant community. Study site **I1** had a significant shrub canopy and site **I2** had no shrub canopy. On study site **I2**, the Wyoming big sagebrush had been removed with a prescribed burn three growing seasons before being sampled. As a results of the prescribed burn, study site **I2** was dominated by western wheatgrass, along with a strong component of bluebunch wheatgrass, plus most of the other native grasses that were present with the sagebrush. However, no sagebrush was found on the sampled plots of site **I2**. There did not appear to be much difference between the amount of bare ground between these two sites, but site **I2** did have significantly less mulch (litter) on the soil surface.

Climate

The average annual precipitation at Buffalo, WY, is 14.8 inches, of which 76% usually falls between April and September (WRCC, 1997). There is a 50% probability that the first and last date on which the air temperature is below 32.5 °F are May 5 and September 18, respectively. There is a 50% probability that the will be 125 consecutive days where the minimum temperature does not fall below 32.5 °F (WRRC, 1997a).

Soils

Soils at the two sites were in the Forkwood Series. They are mapped as Forkwood silt loam. These soils are classified as fine-loamy, mixed, mesic Ustic Haplargids. Forkwood soils are deep and well drained (USDA, SCS, 1990b). Parent material for the mapping units at these sites is moderately weathered alluvium from interbedded sedimentary rocks. The NSSL pedon numbers for the representative soil pedon at each site are 92P0926, and 92P0931 for sites **I1** and **I2**, respectively. Tables 1a, 1b, 2a, and 2b present some selected soil chemical and physical properties for study sites **I1** and **I2**.

Bulk density was sampled on six plots at each study site using the balloon excavation method. Bulk density was measured at three positions and two depths before and after rainfall simulation. Table 3 presents the field measured, plot-average bulk density determined at study sites **I1** and **I2**. The average and standard deviation of **aggregate stability** (method 4G1, USDA, NRCS, 1996) of the surface horizon of the 5 intensively sampled pedons at study site **I1** were **17.3%** and **8.2%**, respectively. The respective values at study site **I2** were **30.0%** and **6.6%**.

Table 1a. Some selected soil properties of National Soil Survey Laboratory pedon number 92P0926 at study site **I1** in Wyoming.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry ($g\ cm^{-3}$)	Coarse fragments (% by weight)
A	0-12	L	34.9	41.5	23.6	-.-- 1/	6
AB	12-19	CL	30.2	40.2	29.6	-.--	1
Bt1	19-36	CL	23.6	43.4	33.0	1.56	Tr 2/
Bt2	36-61	CL	22.0	43.2	34.8	1.69	Tr
Bk	61-108	SICL	17.0	44.8	38.2	1.65	3
2Btk	108-135	CL	21.8	42.8	35.4	-.--	3
2Btz	135-200	SICL	17.9	46.1	36.0	-.--	Tr

1/ measure not taken on sample

2/ Tr = Trace Amount

Table 1b. Some selected soil properties of National Soil Survey Laboratory pedon number 92P0931 at study site **I2** in Wyoming.

Horizon	Horizon depths (cm)	Texture (lab. class.)	Total sand (%)	Total silt (%)	Total clay (%)	Bulk density oven-dry (g cm^{-3})	Coarse fragments (% by weight)
A	0-5	L	44.1	34.0	21.9	-.--	12
Bt1	5-15	C	27.6	30.2	42.2	1.57	2
Bt2	15-34	CL	24.3	39.3	36.4	1.53	2
Btk	34-54	CL	29.7	37.1	33.2	1.52	7
2Bk1	54-83	CL	33.3	35.5	31.2	-.--	22
2Bk2	83-126	CL	31.0	36.4	32.6	-.--	13
2C	126-154	L	44.8	29.4	25.8	-.--	27
3Ab	154-200	CL	25.4	38.5	36.1	1.34	3

Table 2a. Additional selected soil properties of National Soil Survey Laboratory pedon number 92P0926 at study site **I1** in Wyoming.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-12	2.21	-	Tr	15.9	7.5
AB	12-19	1.57	-	Tr	18.0	8.3
Bt1	19-36	0.99	-	0.14	17.0	8.4
Bt2	36-61	0.55	-	0.13	15.9	8.6
Bk	61-108	0.34	-	0.17	16.3	8.8
2Btk	108-135	0.29	-	Tr	15.4	8.8
2Btz	135-200	0.29	-	Tr	15.1	8.8

1/ Walkley-Black

2/ Kjeldahl

3/ Converts to available water capacity (AWC) when corrected for salts and rock fragments, neither of which are significant for this pedon.

Table 2b. Additional selected soil properties of National Soil Survey Laboratory pedon number 92P0931 at study site **I2** in Wyoming.

Horizon	Horizon depths (cm)	Organic carbon 1/ (%)	Total 2/ Nitrogen (%)	Water retention difference 3/ (<2mm fraction)	CEC (meq 100 g^{-1} soil)	Reaction (pH)
A	0-5	1.76	-	Tr	15.2	6.5
Bt1	5-15	1.12	-	0.11	24.8	6.7
Bt2	15-34	1.09	-	0.13	20.7	8.0
Btk	34-54	0.95	-	0.12	17.4	8.2
2Bk1	54-83	0.84	-	Tr	17.2	8.5
2Bk2	83-126	0.86	-	Tr	18.3	8.4
2C	126-154	0.46	-	Tr	15.3	7.7
3Ab	154-200	3.52	-	0.11	36.8	7.6

1/ Walkley-Black

2/ Kjeldahl

3/ Converts to available water capacity (AWC) when corrected for salts and rock fragments, neither of which are significant for this pedon.

Table 3. Field Bulk density (g cm^{-3}) for study sites in Wyoming.

Sample time and depth	Site I1	Site I2
before dry run, 0-1"	1.22	1.02
before dry run, 1-4"	1.07	1.22
before dry run, 0-4" (weighted average)	1.11	1.17
after very wet run, 0-1"	0.88	1.13
after very wet run, 1-4"	1.07	1.10
after very wet run, 0-4" (weighted average	1.02	1.10

Management History

Site **I1** and **I2** were located in the same 699-acre pasture. This area was historically a resting and holding area for large numbers of sheep during sheep drives. It is currently used in a rotational system as a cattle resting and holding area and for cattle grazing. Season of use varies with range conditions. The year of sampling, the area was used in early spring. The preceding 2 years, it was used in the fall. The area is also used during the winter. The pasture was prescribed burned in fall, 1989. The area where site **I1** was located was not affected by the burn but the area where site **I2** was located had shrub cover completely removed. No other range treatments have been applied at sites **I1** and **I2**.

Vegetation

The canopy and ground surface cover were sampled on six plots at each study site. Table 4 presents the study site plot-average. The annual yield, dead standing biomass, and soil surface residue were also sampled on the same six plots at each site. Table 5 presents their plot-average values. Annual production of pricklypear (*Opuntia* P. Mill.) was assumed to be 10% of standing live biomass. Annual production of big sagebrush and birdfoot sagebrush (*Artemisia pedatifida* Nutt.) was assumed to be 30% of standing live biomass of leaves and non-woody stems. Live woody stem total biomass was recorded separately.

Below ground root biomass was also measured for all plots at each study site. Areas in plant interspaces and under plant canopies were sampled separately at study site **I1**. At study site **I2,** a relatively uniformly spaced plant community with no interspaces was present at the sites, therefore only a single type of surface area was sampled. Table 6 presents the surface, sub-surface, and total plot-averaged values for each study site and surface type.

Table 4. Canopy and ground cover (%) for study sites in Wyoming.

Cover category	Site I1	Site I2
Grass	19.4	41.9
Forb	1.6	5.9
Shrub	28.2	0.0
Cactus	0.1	0.0
Half-Shrub	0.0	0.0
Standing Dead	5.5	22.6
Total canopy cover	**54.7**	**70.4**
Basal vegetation	5.4	3.9
Cryptogam <1cm	0.1	0.0
Cryptogam >1cm	0.0	0.0
Litter	55.6	54.9
Rock	0.5	4.6
Bare soil	38.4	36.5
Total ground cover	**61.6**	**63.5**

Table 5. Average above ground biomass for the 6 plots, in pounds per acre of oven dry weight for Wyoming sites. Value of 0.0 denotes an absence of plants from the site, and "Tr" denotes a trace occurance of the respective species on the site.

common name (species name)	**Site I1** (shrub site)	**Site I2** (grass site)
Native grasses and sedges		
prairie Junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schultes)	229.3	56.6
western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love)	92.9	566.3
green needlegrass (*Stipa viridula* Trin.)	54.2	61.1
Sandberg bluegrass (*Poa secunda* J. Presl)	32.5	10.6
bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *spicata* (Pursh) A. Love)	11.6	177.2
blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)	4.7	0.0
threadleaf sedge (*Carex filifolia* Nutt.)	Tr	0.0
Total of native grasses and sedges	**425.4**	**871.9**
Native forbs and other herbaceous plants		
spiny phlox (*Phlox hoodii* Richards.)	47.2	2.9
pussytoes (*Antennaria* Gaertn.)	5.6	0.0
American vetch (*Vicia americana* Muhl. ex Willd.)	0.4	23.7
scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb.)	0.1	45.5
knotweed (*Polygonum* L.)	0.0	0.1
common dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers)	0.0	23.0
prairie fleabane (*Erigeron strigosus* Muhl. ex Willd.)	Tr	0.0
pepperweed (*Lepidium* L.)	Tr	11.0
Total of native forbs and other herbaceous plants	**53.5**	**106.4**
Native shrubs and cacti		
big sagebrush (*Artemisia tridentata* Nutt.)	475.9	0.0
birdfoot sagebrush (*Artemisia pedatifida* Nutt.)	12.0	0.0
pricklypear (*Opuntia* P. Mill.)	5.5	0.0
Total of native shrubs and cacti	**493.5**	**0.0**
Introduced grasses		
Japanese brome (*Bromus japonicus* Thunb. ex Murr.)	Tr	28.6
cheatgrass (*Bromus tectorum* L.)	Tr	0.0
Total of introduced grasses	**Tr**	**28.6**
Introduced forbs and other herbaceous plants		
yellow salsify (*Tragopogon dubius* Scop.)	0.2	0.0
mustard (*Brassica* L.)	0.0	0.1
Total of introduced forbs and other herbaceous plants	**0.2**	**0.1**
Total average live plant annual yield	**972.8**	**1007.1**

Table 5 continued

Soil surface residue and standing dead plant material		
standing-live wood	6337.8	0.0
non-woody litter	1103.3	796.4
standing-dead wood	757.4	1238.9
woody litter	526.1	115.1
manure	1.9	88.1
standing-dead grass	0.0	307.8
Total of soil surface residue and standing dead plant material	**8726.8**	**2546.5**

Table 6. Root biomass in pounds per acre, oven dry weight, for study sites in Wyoming.

	Under Plant Canopy [1/]		Plant Interspace [2/]	
Sample depth	**Site I1**	**Site I2**	**Site I1**	**Site I2**
0-1"	3264.6	1393.0	855.5	-
1-4"	2975.4	1775.7	1332.6	-
0-4" (total)	**6240.0**	**3168.7**	**2188.1**	-

1/ Samples taken in area under plant canopies.
2/ Samples taken in open areas not under plant canopies.

Hydrology

All 36 plot-runs near Buffalo, WY, were considered suitable to be included in analyses. Three of the dry plot-runs and 1 of the wet plot-runs at site **I1**, and 1 of the dry and 1 of the wet plot-runs at site **I2** had less than 1 mm total runoff. Plot-runs with less than 1 mm total runoff may be considered as within the region of measurement error and should be considered as potentially 0 mm runoff. The inclusion of these plot-runs will depend on the specific analysis. Table 7 presents a summary of some pertinent hydrologic results.

Table 7. Hydrology Results for study sites in Wyoming. Tabled values are arithmetic averages across plots at a site. Sample size may not be 6 in all cases.

Description	Site I1	Site I2
Dry plot-runs at antecedent soil moisture		
Total rainfall (mm)	55.86	54.86
Uniform rainfall rate (mm h^{-1})	55.86	55.80
Rainfall duration (minutes)	60.00	59.00
Total runoff (mm)	2.96	7.75
Runoff to rainfall ratio (mm mm^{-1})	0.05	0.14
Time to start of runoff (minutes)	9.28	4.74
Peak runoff rate (mm h^{-1})	5.02	14.11
Time to peak runoff (minutes)	51.83	45.83
Initial abstraction depth (mm)	9.03	4.80
Recession depth (mm)	0.12	0.46
Total sediment yield (kg ha^{-1})	77.57	113.54
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	17.46	10.16
Equilibrium infiltration rate (mm h^{-1})	51.38	39.99

Table 7 continued

Wet plot-runs 24 h after dry plot-runs		
Total rainfall (mm)	25.06	30.53
Uniform rainfall rate (mm h^{-1})	56.45	58.55
Rainfall duration (minutes)	26.67	31.33
Total runoff (mm)	3.55	10.19
Runoff to rainfall ratio (mm mm^{-1})	0.14	0.36
Time to start of runoff (minutes)	5.28	5.10
Peak runoff rate (mm h^{-1})	14.86	33.29
Time to peak runoff (minutes)	21.83	24.00
Initial abstraction depth (mm)	5.56	5.50
Recession depth (mm)	0.48	1.48
Total sediment yield (kg ha^{-1})	83.77	113.08
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	17.93	9.13
Equilibrium infiltration rate (mm h^{-1})	42.90	20.78

Very wet plot-runs 30 minutes after wet plot-runs		
Total rainfall (mm)	66.93	67.46
Rainfall duration (minutes)	56.00	56.67
Total runoff (mm)	26.66	46.50
Runoff to rainfall ratio (mm mm^{-1})	0.41	0.70
Time to start of runoff (minutes)	3.43	3.21
Peak runoff rate (mm h^{-1})	64.54	95.38
Time to peak runoff (minutes)	33.33	34.00
Initial abstraction depth (mm)	3.57	3.19
Recession depth (mm)	0.82	1.82
Total sediment yield (kg ha^{-1})	469.88	484.28
Sediment yield to runoff ratio (kg ha^{-1} mm^{-1})	15.94	9.31

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